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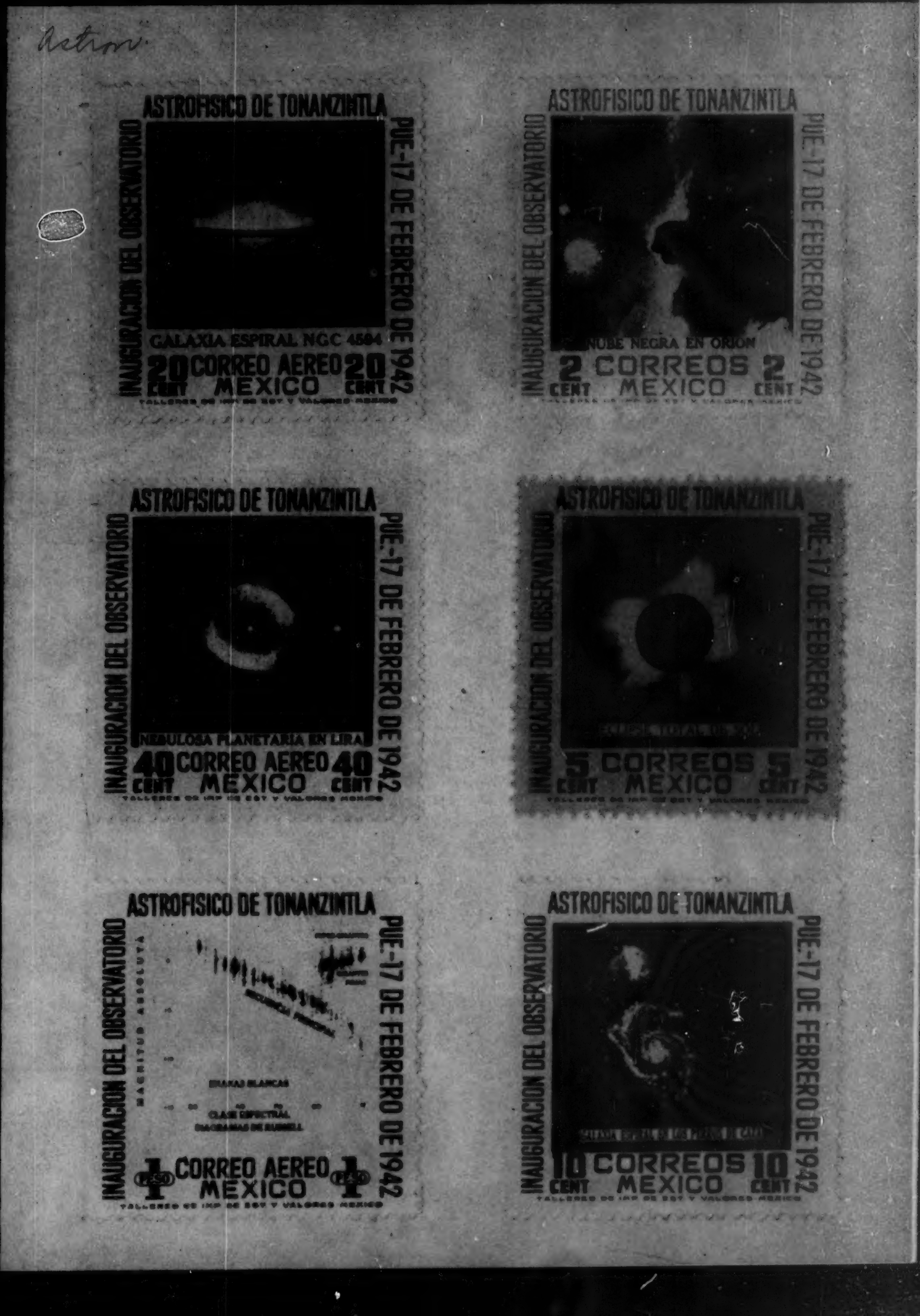
Astron.



ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
GALAXIA ESPIRAL NGC 4594
20 CENT CORREO AEREO 20 CENT
MEXICO
ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
NUBE NEGRA EN ORION
2 CENT CORREOS 2 CENT
MEXICO
ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
NEBULOSA PLANETARIA EN LIRA
40 CENT CORREO AEREO 40 CENT
MEXICO
ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
5 CENT CORREOS 5 CENT
MEXICO
ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
MAGNITUD ABSOLUTA
ENANAS BLANCAS
CLASE ESPECTRAL
DIAGRAMAS DE RUSSELL
1 PESO CORREO AEREO 1 PESO
MEXICO
ASTROFISICO DE TONANZINTLA
INAUGURACION DEL OBSERVATORIO
PUE-17 DE FEBRERO DE 1942
10 CENT CORREOS 10 CENT
MEXICO

Sky and TELESCOPE

The Editors Note . . .

ALTHOUGH not having the authority of even amateur philatelists, we venture to say that Mexico's recent issue of six stamps commemorating the dedication of the Tonanzintla Observatory produces some of the first stamps using strictly astronomical themes to mark an event of astronomical import. Stars and planets, the sun and moon, have been included in many stamps; the Southern Cross is a favorite with southern countries; but usually the main theme of a stamp is not astronomical, even if it contains stars used symbolically. Occasionally, an observatory is pictured (see Dr. Roy K. Marshall's article on astronomical stamps, The SKY, July, 1938), but that is still a terrestrial object. These new stamps are celestial—sidereal—and to appreciate them requires some knowledge of modern astronomy and astrophysics.

Sets of the stamps may be purchased from the Officina Philatelica, Officina de Correos, Mexico, D.F., Mexico, or from reputable stamp dealers in the United States.

Frequent bombings during a 160-day round-trip journey by open truck, two weeks' rain during their testing period, and the non-arrival of their best camera could not stay persevering Chinese astronomers from observing and photographing successfully the total solar eclipse of September 21, 1941. Except for a letter from Foster D. Brunton in Guam (December, 1941, *Sky and Telescope*), the report from Dr. Y. C. Chang, appearing in the April issue of *Popular Astronomy,* is the first received. It includes pictures of a corona of circular form—usual during minimum sunspot period.

The Chinese astronomers journeyed in an open truck from Kunming, Yunnan province, where the National Institute of Astronomy is now located, 3,200 kilometers to Lintao, Kangsu, in northwestern China. During totality they measured the light of the corona, made color motion pictures, took movies from a light bomber, and, "following the practice of American eclipse expeditions," broadcast the eclipse. Their efforts were supported by the Chinese government.

VOL. I, No. 7 MAY, 1942

CONTENTS

COVER: The series of six stamps issued by the Mexican government on the occasion of the dedication of the National Astrophysical Observatory at Tonanzintla. The subjects are: **(left column)** spiral galaxy NGC 4594, Ring nebula in Lyra, Russell diagram, **(right column)** dark nebula in Orion, total eclipse of the sun, spiral galaxy in Canes Venatici.

BACK COVER: Direct photograph of a large sunspot group near the center of the sun's disk, by Philip C. Keenan, July 10, 1937, with the 40-inch refractor, at Yerkes Observatory. (See "In Focus," page 17.)

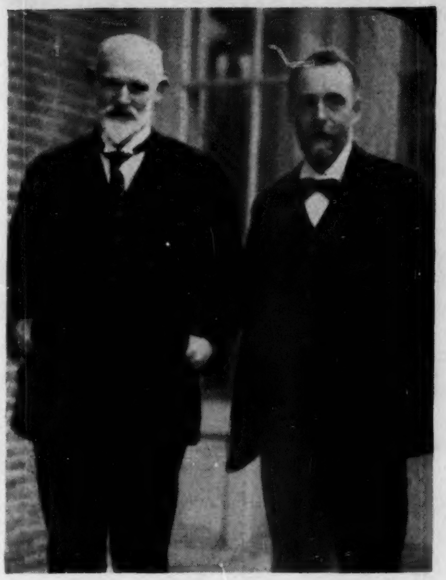
SKY AND TELESCOPE is published monthly by Sky Publishing Corporation. Editorial and general offices: Harvard College Observatory, Cambridge, Mass.

Subscription: $2.00 per year in the United States and possessions; $2.50 foreign (including Canada). Single copies: 20 cents. Make checks and money orders payable to Sky Publishing Corporation; send notice of change of address 10 days in advance.

Entered as second class matter, April 28, 1939, at the Post Office, New Rochelle, N. Y., under Act of March 3, 1879.

The Diagnosis of Stars from Their Spectra

By Dorrit Hoffleit
Harvard College Observatory



Dr. E. Hertzsprung, director of Leiden Observatory, and discoverer of the distinction between the luminosities of giants and dwarfs, is shown here with Dr. W. de Sitter (*at left*), former director of the same institution. Photograph by David B. Pickering.

THE spectra of the stars—those tiny rainbows we observe when starlight passes through a prism—serve the astronomer somewhat similarly to the way that X-rays serve the physician. Of course, the spectrum of a star does not show us anything very far beneath the surface of the star, as the X-rays do of us humans; the analogy lies rather in the specificness of the information acquired.

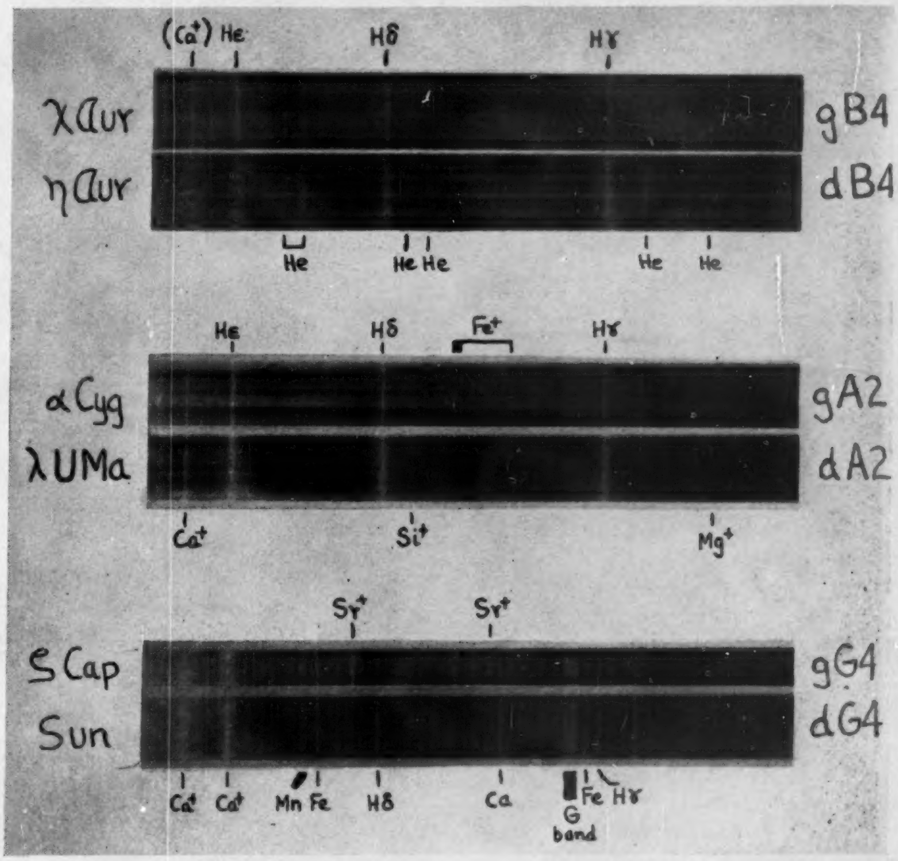
Direct photographs or visual observations reveal comparatively few of a star's characteristics. A single photograph tells us only the apparent brightness and apparent location in the sky. Numerous photographs of a star, properly planned, can reveal its variability (if any), parallax, apparent motion perpendicular to the line of sight, and the color (from which the temperature may be inferred). Unless the star happens fortunately to be one component of a recognized double star, this is about all that the direct photographs will indicate.

The spectrum, on the other hand, gives us much additional information. It is a familiar fact that the lines in any spectrum are characteristic of the chemical elements of the source. Likewise, the story of spectral classification and its subsequent interpretation in terms of the temperatures of the stars has often been related. (See *The Telescope,* March-April, 1941, "Stellar Spectra and the Diagnosis of Stars.") These I shall only mention here, and pass on to other considerations—some less revolutionary, perhaps, than the early discoveries of the chemistry and temperatures of the stars, but nevertheless significant.

By 1901, the Draper system of spectral classification had been fairly well perfected. Other schemes were indeed in frequent use, but the various systems were for the most part closely correlated, many of the differences being merely in notation. On the Draper system, every star is uniquely classified along a one-dimensional sequence, which to a first approximation is an arrangement by color, and in the last analysis is a temperature arrangement. Such a one-dimensional sequence was consistent with the then most acceptable theories of stellar evolution.

In 1907, however, the great Danish astronomer, Hertzsprung, found, from a comparison of their relative distances and apparent brightnesses, that all stars of the same spectral class are not similar. Among the orange and red stars, for example, some are very large and very luminous, while others are small and faint. These two classes of stars he is said to have nicknamed giants and dwarfs, names the stars have retained legitimately ever since.

Hertzsprung could not believe that stars which differed perhaps a hundredfold in real brightness should not show differences in their spectra. He, himself, did not have available any spectra to examine. But he made use of the admirably detailed descriptions of spectra published by Miss Antonia C. Maury at Harvard College Observatory. From her descriptions he found that the spectra of his giant stars did actually differ from the dwarfs in two respects. In the first place, the lines of the spectra of the highly luminous stars were exceedingly sharp, whereas the lines in the dwarf spectra were diffuse and relatively ill-defined. Then, among the less conspicuous lines, he discovered that some were much more prominent in the giants



The differences between the spectra of giant and dwarf stars are shown here. The upper spectrum of each pair is the giant. In χ Aurigae and α Cygni, the lines are sharper than in the dwarfs of the same spectral type. In ζ Capricorni, a giant, the lines of ionized strontium are much more conspicuous than in the dwarf sun (both are G-type stars).

The line in χ Aurigae marked Ca+ is due to interstellar calcium, indicating the stars's great distance compared with η Aurigae. These spectra, by W. W. Morgan, of Yerkes Observatory, are reproduced from *The Milky Way,* by Bok and Bok, courtesy, the Blakiston Company.

than in the dwarfs. This latter characteristic was later independently discovered by Adams and Kohlschütter at Mt. Wilson Observatory, where it has since been put to the very practical use of determining the absolute magnitudes and distances of the stars.

The absolute magnitude, you will recall, is a quantity defining the true brightness of a star. The apparent magnitude tells us how bright a star looks. The absolute magnitude tells us how bright it would look if all the stars were at a standard distance from us—10 parsecs, 33 light-years.

Suppose we have two stars of the same temperature and the same composition, but of different size. The larger star will then, naturally, be the brighter. It also turns out that the pressure is less in the atmosphere of the larger star. We know, both from theoretical considerations and from experiments in physics laboratories, that gases are more easily ionized (robbed of electrons) at low than at high pressures. Applying this information to stellar atmospheres, we should expect ionized atoms to be more prominent in bright, large stars than in the dwarf stars of the same temperature. This is precisely what Adams and Kohlschütter found. Hence, in order to discover the relative true brightnesses of the stars, all we need do is to estimate from their spectra the comparative abundances of the ionized elements.

The most satisfactory way to find the distances of the nearby stars has been by triangulation, the diameter of the earth's orbit being used as a baseline. That method is, however, uncertain for stars farther away than 100 or so light-years; and it is hopeless for stars 1,000 light-years away. Such distances reach hardly a tenth of the way from here to the center of our own Milky Way galaxy.

By our spectroscopic method, we can determine the true brightness of a star. We already know how bright it looks. Hence, it is an easy matter to compute its distance (provided nothing obstructs the starlight appreciably). For the relatively nearby stars we find that the distances determined spectrographically compare very well with the distances found by the triangulation method. We can, however, measure the spectra of the very distant stars with the same degree of accuracy as the spectra of the nearby stars. In this respect, the larger telescopes and more efficient spectrographs are coming to our aid, enabling us to gather more light from the faint stars and thus to extend to greater distances our investigations of the distribution of the stars.

The luminosities themselves show an interesting distribution. We find that the majority of the giant stars, supergiants excluded, have nearly the same intrinsic brightness (within a factor of about 10), regardless of their temperatures. The dwarf, or main-sequence stars, as they are often called, show an entirely different state of affairs. The blue, hot stars are all very bright, of the order of 100 times brighter than the sun. The yellow dwarfs are like our sun. Big as the sun seems to us, it is merely a dwarf among the stars. But it is very much brighter than the *red* dwarf stars, which may be several thousand times fainter.

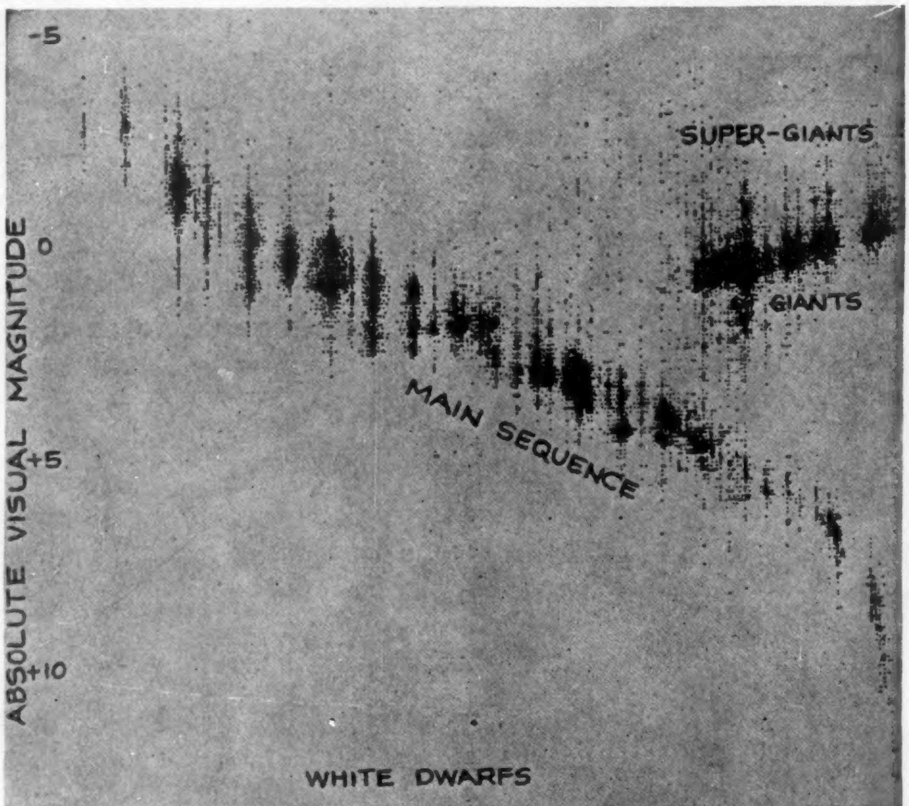
Prof. Henry Norris Russell was the first (1913) to illustrate this systematic array into which stellar temperatures and luminosities could be arranged. For him it formed the basis of a theory of the evolution of the stars. This theory had had early forerunners, notably one by Sir Norman Lockyer, but in Russell's investigations it first attained logical perfection combined with apparent observational support.

According to the theory, a star begins its life as a red giant star, rosy and puffed with the very pride of existence. As it grows older it shrinks, and while it shrinks it becomes hotter and hotter, and hence bluer. Finally it reaches a maximum temperature: it has become too hot for its increased density. It then begins to cool, and as it cools, keeps on shrinking, but now at a faster rate than before. It therefore becomes both fainter and redder. This was considered the general scheme of a star's life: from red giant to a hot, blue star; from a bright, blue star to a yellow dwarf; and in its ripe old age, a red dwarf.

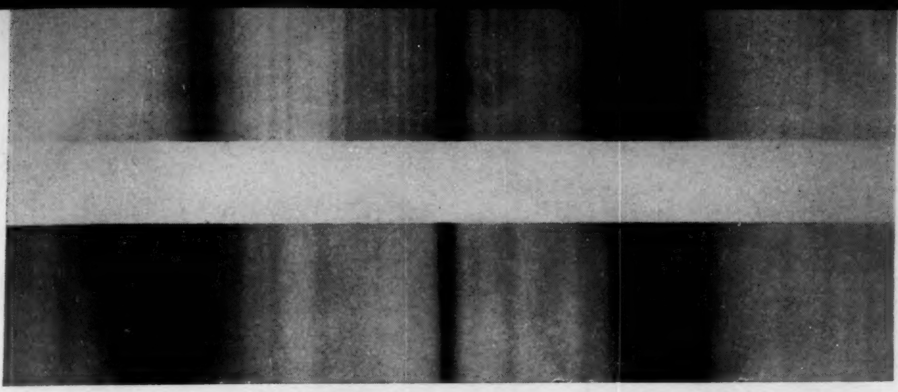
Naturally, the human race has not had time to observe changes from giant to dwarf in any single star. We can merely see how a star, the sun for example, is radiating *now*, and predict how it might have appeared in the past and where its present activity should lead it. If we can find other stars satisfying our descriptions of the probable past and future of the sun, then we may have a tolerable, cautious sort of faith in our theory.

Just when Russell's original theory was held in the greatest esteem, because it accounted so well for all the observed facts about the stars, a remarkable discovery was made which seemed to throw doubt on everything. We saw that the theory predicted one variety of hot, blue stars, and both giants and dwarfs among the cooler stars. Now it happens that the bright Dog Star, Sirius, has a faint companion revolving around it, so close to Sirius that for many years it was impossible to obtain its spectrum or determine its color. But, knowing the distance of Sirius, astronomers could ascertain unequivocally that the companion is a faint dwarf. No one ever thought of questioning the inference that the star must be a red dwarf.

In 1915, Adams at Mt. Wilson at last succeeded in photographing its spectrum. Astronomers felt skeptical; they were embarrassed; in fact, they would not believe. Spectra do not lie. Yet this spectrum could not be telling the truth. For it said



The Russell-Hertzsprung diagram shows the relationship between absolute magnitudes and spectral classes.



The spectrum of Beta Aurigae, a spectroscopic binary, showing alternate doubling of the K line of ionized calcium. The extremely broad lines on the right and left are, respectively, Hε and Hζ, of the hydrogen Balmer series.

the star is blue and hot, not red and cool. Combining the spectroscopic information with other available data about the strange star, astronomers computed its density. Although the companion of Sirius is only the size of the earth, it is so heavy that one teaspoonful of the material of which it is composed weighs one ton. There was a tendency to avoid talking about so scandalous a liar—such stars simply could not exist.

Finally, however, Eddington, who had been working on the internal constitution of the stars, found that his theory actually demanded not only the normal giant and dwarf stars ordinarily observed, but also some very dense, hot, blue stars. Immediately the companion of Sirius achieved good standing, and became the savior of a more mature theory than the one it seemed to be denying.

Stars like this *white* dwarf are intrinsically so faint that they must be as near as 30 light-years to be seen as 10th-magnitude stars, that is, 50 times fainter than the naked eye can detect. Not long ago it was thought that nothing of particular interest remained to be discovered within 30 light-years of the earth. But these faint stars have become most intriguing. Like the needle in the haystack, they are nearby, yet extremely difficult to discover. There are many 10th-magnitude stars in the sky; but most of them are normally luminous stars situated at great distances. The spectroscope helps us separate the nearby dwarfs from the more distant familiar species. Nowadays the fascination of the nearby stars lies not (as in the time of Bessel and Wilhelm Struve) in the struggle to find their distances, but in the elusiveness of the stars themselves. This much the spectrum of one white dwarf has taught us.

There are other facts of a different character to be pried out of our informative little stellar rainbows. We know that light has speed: it travels about 186,000 miles a second. If a source of light is moving toward or away from us, however, the relative speed of the light is unaffected, but the wave length is changed. Consequently, if a star's motion is toward us, all of the lines in its spectrum will be displaced toward the blue from their normal positions. Similarly, when a star is running away from us, all the spectral lines must be shifted toward the red. The amount of the shift depends on the speed of the source compared with the speed of light, and also on the wave length. This phenomenon is called the Doppler effect.

Such shifts in the spectra of the stars were first studied by Sir William Huggins in 1868. The displacements of the stellar lines are, however, very small, and measurements of the Doppler shift have attained a high degree of accuracy only since the advent of systematic celestial photography. These give us, of course, only one component of the motion of a star, that in the direction of the line of sight. If a star is moving exactly perpendicular to that direction, no Doppler shift will be observed. Motions away from us, producing red shifts, are *positive;* motions toward us, *negative.*

From their spectra, such radial velocities of more than 7,000 stars have been determined. We find that some move sluggishly while others are rather peppy. On the average, the hot, blue stars move about very slowly (like people in hot weather). The cool, red stars have more dynamic energy and rush around at about twice the average speed of the blue ones.

The positive radial velocities of the extragalactic nebulae, determined from Doppler shifts in their spectra, provided the observational basis for an important theory, Lemaitre's expanding universe. Unless the universe is expanding, why should all the distant galaxies appear to be running away from us? Curvature of space and the theory of relativity may give an answer.

The Doppler principle has also been applied to the study of duplicity among the stars. In 1889, it was discovered at Harvard that the spectrum of the star ζ Ursae Majoris (Mizar) sometimes showed single, sometimes double, lines. This doubling was soon interpreted to mean that the star itself consisted of two stars revolving around one another, but so close together that to the eye they appeared as one star. Part of the time both stars are in nearly the same direction as seen from the earth, but moving in opposite directions across the line of sight. At that time, the lines from the two stars are superposed in the spectrum. Later, when the stars have moved 90 degrees in their orbits, one of the components is approaching us, while the other is receding. Now the spectral lines of the two components are displaced in opposite directions.

Sometimes one of the two components of a double star is much fainter than the other, and does not show any lines in the observed spectrum. In such cases, the double nature of the star is revealed by the periodic changes of position of the lines representing the bright star only. From such periodic oscillations of their spectral lines, over 1,000 stars have been found to be double—they are called spectroscopic binaries.

Rotation in the stars is also discovered by means of the Doppler effect. We know from the motions of sunspots that the sun rotates. Some of the stars must likewise be in rotation. Just as in the case of double stars, where one component is moving away from us while the other is coming toward us, so in the case of a rotating star (if its axis is sufficiently inclined to the line of sight), one edge is receding while the other is approaching, and the middle section of the star is relatively standing still. Hence, we expect to find a widened, hazy-looking line instead of a sharp one. The total width of the line indicates the speed of rotation. Qualitatively good results may be obtained from this method, but the effect is sometimes difficult to evaluate, for there are other possible reasons for the widening of spectral lines—pressure and gravitational effects and turbulent atmospheres. Dr. Jesse L. Greenstein, in another article in this issue, discusses some of these problems.

There are yet other facts that may be learned from stellar spectra. For instance, they can tell us a good deal about the dust or gases that inhabit the space between the stars. Spectral lines due to interstellar material give clues to the distances of very remote stars. Recently, they have prompted theories on the refueling of stars whose private hydrogen supply could not have kept the stars shining nearly long enough. Interstellar space is large, and dense, not with material things, but with problems for the astronomer and with fuel for his theories.

Stellar spectra have told us about the temperature, composition, brightness, pressure, speed, duplicity, and rotation of the stars; and they indicate the nature of obscuring matter between us and the stars. In conjunction with other information, notably the comparatively easily determined apparent brightnesses, they also tell us how far away the stars are. In addition, the spectra are the most important data for formulating and checking theories on stellar evolution and on the interiors of the stars.

But just like the human body, which after centuries of research has not revealed all its minute mechanisms to the medical student, so the stellar spectrum still has much to reveal to us about the stars. Nor is spectrum analysis in any sense monotonous investigation—each newly discovered fact opens vistas for further exploration.

DO YOU KNOW?

By L. J. Lafleur

I. Score four points for each question correctly answered, and one point for each question where you do not attempt to select the answer.

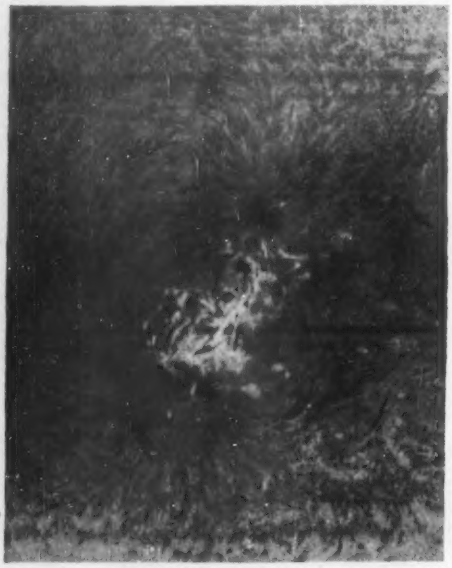
1. The autumnal equinox is the time when the sun is
   a. its extreme distance south of the equator
   b. its extreme distance north of the equator
   c. on the equator going north
   d. on the equator going south
2. One of the following constellations does not contain part of the Milky Way:
   a. Cepheus c. Scutum
   b. Coma Berenices d. Lacerta
3. The density of the earth (water = 1) is approximately
   a. 5½ c. 10½
   b. 7½ d. 13½
4. The ecliptic passes through
   a. Triangulum c. Eridanus
   b. Lupus d. Capricornus
5. A millimicron is a
   a. thousandth of an inch
   b. millionth of a centimeter
   c. thousandth of a millimeter
   d. millionth of a millimeter
6. One of the following events is impossible:
   a. Venus appears in Bootes
   b. Mercury appears in Sextans
   c. Mars appears in Orion
   d. Uranus appears in Ophiuchus
7. For convenience, assume the moon's distance to be a quarter of a million miles, its period 28 days. If a small body circled the earth at a distance of a million miles, its period would be about
   a. 70 days c. 448 days
   b. 224 days d. 1,792 days
8. There is at least one star brighter than the 4th magnitude in
   a. Scutum c. Pyxis
   b. Equuleus d. Musca
9. The apparent diameter of a star as seen in a telescope varies as the
   a. diameter of the telescope
   b. inverse of the diameter of the telescope
   c. square of the diameter of the star
   d. square root of the diameter of the star
10. The path of the sun through the galaxy fluctuates because of the gravitational influence of the planets. The extreme range possible is about
    a. 1,000 miles c. 100,000 miles
    b. 10,000 miles d. 1,000,000 miles

II. In what constellation is each of the following well-known nebulae found? Count three points for each correct answer.

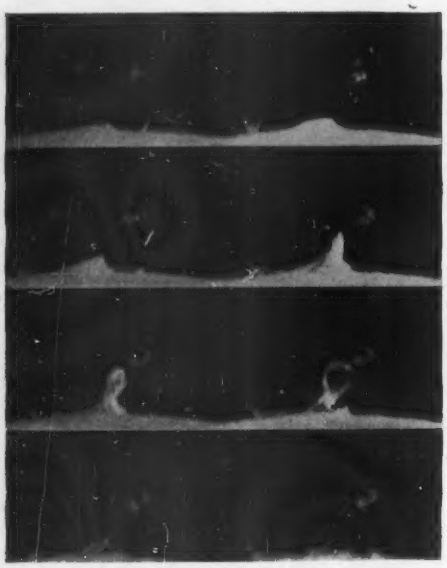
1. Crab
2. Dumbbell
3. Great (Spiral)
4. Horsehead
5. North America
6. Ring
7. Tarantula
8. Trifid
9. Veil
10. Whirlpool

III. The accompanying photographs are captioned by letter only. Count three points for each identification and two points additional for each complete caption you can furnish.

(*Answers on page 18*)

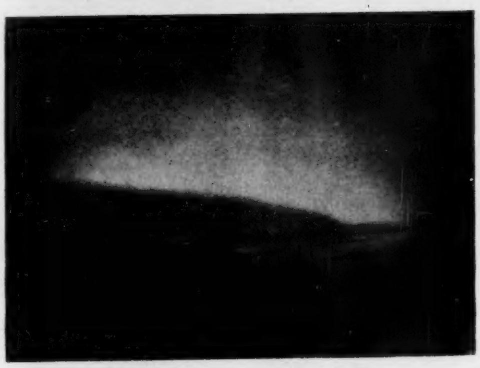


A.

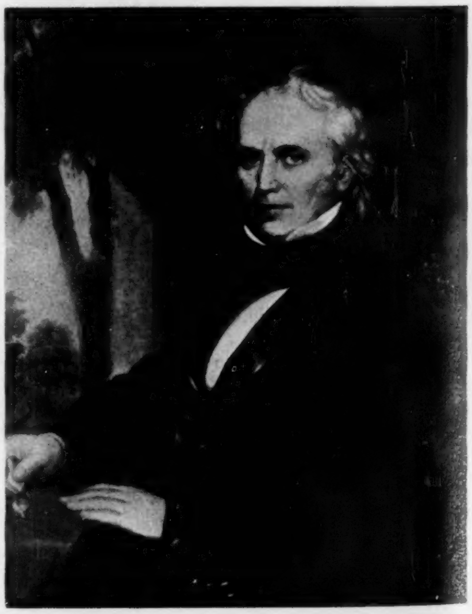


B.

C. (*above*) D. (*below*)



E. (*above*) F. (*below*)



CORRECTIONS TO APRIL ISSUE

On page 8, *An Amateur Looks at Mars,* line 4-5 should read in part: "comparable to those found on drawings 5 and 6" (instead of "1 and 2").

On page 9, the cuneiform inscription is identified by Dr. Woolard as being of the 5th century B.C., instead of as stated in the caption, which did not have the author's inspection.

On page 12, 2nd column, fifth line from bottom, change "100,000" to "100,000,000."

*See correction in "Answers to Do You Know."

WEATHER SIGNS IN THE SKY

By William H. Barton, Jr.

The weather, its causes, effects, and legends are discussed here and in the Hayden Planetarium this month. Today, more than ever, it is worth knowing good and bad weather signs, and which weather "maxims" are sound or unsound.

WEATHER information now is a military secret. There is no weather map. Newspapers and other public information agencies are restricted in the descriptions of weather which they may publish. Therefore, if we are interested in forecasting our weather we are really on our own. We may not do as good a job as the Weather Bureau, but if we know good signs from bad ones, we can gain some idea of what tomorrow's sky may be. Long before weather forecasting was the important science it is today, the farmer, the mariner, and the amateur meteorologist were forecasting by weather signs in the sky.

It turns out that most of these old signs belong in the category of "goosebone" weather prophecy, still practiced in some rural communities, either seriously or as a tradition. On the other hand, some of the warnings in the sky are good elementary meteorology. But to understand them an amateur meteorologist must know a few of the modern theories concerning weather, and have fairly long experience observing weather changes in his own locality. And although he may want only to foretell and prepare for stormy and "bad" weather, he must study the changes to fair weather during all seasons of the year.

How often we hear an oldtimer bemoan, "Where are the snows of yesteryear?" His memory is stronger than his present observation. The snows and rains of today are as heavy and the storms as violent, *on the average,* as they were 50 years ago, but perhaps our willingness to brave the elements and therefore experience the full effect of modern storms is lessened. Nature is economical, cyclic, conservative. If she were not, we would never have discovered any of her methods. She repeats incessantly, and we finally catch on to her tricks.

Fundamentally, weather is largely dependent on the nearest of the stars; it begins with the release of energy inside the sun. This energy comes to us in several forms, but mostly as radiant energy of all wave lengths, not just as visible light. The normal infrared and visible radiation from the sun warms the atmosphere and the land and the sea. Therefore, it is the sun which evaporates the ocean water, and causes the warm air containing this moisture to rise to where it forms clouds when the temperature drops sufficiently. The unequal warming of land and sea and of the air above them causes wind, which carries the clouds across the earth. Precipitation in the form of rain, snow, hail, or sleet, restores the water to the ocean again where the sun can start the cycle once more.

However, the ultraviolet or short wave lengths in sunlight play an important part in producing changes, not all of which are understood. Ultraviolet light produces layers of electrified or ionized air, some hundreds of miles high; it is from these that radio waves are reflected. Ultraviolet light produces vitamin D in plants and the skins of animals.

To know the weather, then, we must observe the sun. The amount of radiation it sends us is not constant, despite its name: *solar constant.* The variations are small indeed, but their influence is considerable. Dr. Charles G. Abbot, secretary of the Smithsonian Institution, is the world's leader in studies of the solar constant. In the preface to a paper by Henryk Arctowski entitled *On Solar-Constant and Atmospheric Temperature Changes,*[1] Dr. Abbot says:

"What is needed . . . is a continuous daily record of the solar variation over many years, with the individual mean daily solar-constant values probably accurate to one-fifth of 1 percent. It is true that in July 1941 we introduced a new method of noting solar variation, in which the measures are restricted to the blue-violet spectral region where percentage changes are larger and where several sources of error are eliminated. Our three desert mountain stations are now all carrying on these new observations in addition to the older method of solar-constant measurement . . . the requisite certainty and accuracy probably can come only by occupying as many as 10 of the most favorable desert mountain sites to be found in the whole world. War conditions render this impossible for the present."

[1]Smithsonian *Miscellaneous Collections,* Vol. 101, No. 5, 1941.

It has been found that atmospheric pressures and temperatures, over both long and short periods, vary with changes in the sun's radiation. These variations, according to Dr. Abbot, comprise 12 or more regular periodicities, by means of which predictions of solar changes, including the presence of sunspots, may be computed years in advance. These periodicities are integral submultiples of 23 years, such as $11\frac{1}{2}$ years, 68 months, and eight months. In the long run, the weather

The best station for observation of the energy we receive from the sun is located on desert Mt. Montezuma in Chile, where this solar radiation instrument operates daily. Smithsonian Institution photo.

at any one station contains features which tend to repeat themselves at intervals of 23 years or 46 years.

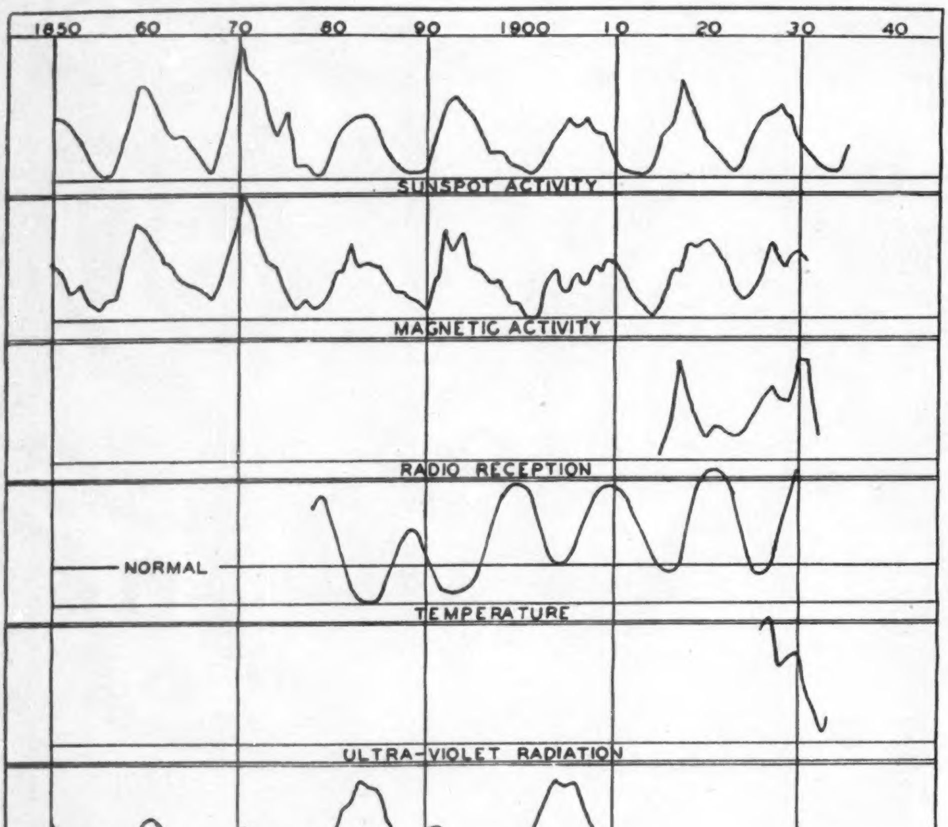
The combination of these periodicities explains why what we usually call the sunspot cycle, 11½ years, is not constant, but may sometimes be as long as 13 or 14 years, and at other times as short as eight years. Just how sunspots are connected with other changes on the sun, such as the activity of prominences, the shape of the corona, and solar radiation, is not known, but we might consider sunspots as visible results of "weather" changes on the sun similar to and resulting from the same causes as those of weather changes on the earth.

Weather is the connecting link between many cyclic phenomena on the earth and on the sun. For instance, as early as 1901 the idea of using tree rings for the purpose of extending available records of solar variations was conceived by Dr. A. E. Douglass, of Steward Observatory. He has built up a system of studying tree-ring widths which has proved of great value to botanists, geologists, archaeologists, and even historians, and his results confirm the effect of solar changes on the earth. No doubt, his study sums up temperature, precipitation, amount of ultraviolet in sunshine, and all the factors of growth.

So far we have been speaking, somewhat vaguely perhaps, of fundamental or primary causes, not merely signs. Most of the directly visible phenomena that are associated with weather forecasting are not causes but effects produced in advance of changes.

These changes themselves result from the interaction of warm and cool masses of air, moving generally eastward over the earth's surface. When these interactions take place, changes in air pressure accompany them, and lead to the development of *high-pressure* and *low-pressure* areas. Where the pressure is low, surface air is drawn into the area, but because of the rotation of the earth, it does not stream directly toward the center of the low-pressure area. Instead, in the northern hemisphere, it circles to the right, and the result is a counterclockwise circulation of air around the low-pressure area. For a high-pressure area, the air is streaming outward, in a clockwise direction.

What we call *weather* consists chiefly of daily variations in temperature, and accompanying changes from clear to cloudy skies, and perhaps, to rain or snow. *Climate,* however, is the average of these factors over long periods. Climate depends on latitude, nearness to large bodies of water, altitude, and other permanent factors, whereas weather depends upon the day-to-day mixing of warm and cool masses of air and their progress across the land.



Correlations of many terrestrial phenomena with sunspot activity have been made, among which those shown above are most generally accepted.

Generally, high-pressure areas bring fair weather. Low-pressure areas are sometimes called *storms,* because they are usually cloudy, and it may rain or snow before, during, or after they have passed a particular place. Winds rush into low-pressure areas—thus the intermingling of cold and warm air is increased. This intermingling inevitably results in the rising of the warmer air, because it is less dense than the colder air. However, sometimes the warm air is stronger than the cold, and may push the cold before it at the same time that it *overruns* it; in this case, we say there is a *warm front* between the warm and cold air. In other cases, the cold air is doing the pushing, and *underruns* the warm air, producing a *cold front.*

But the inevitable pushing or rising of the warm air to greater altitudes will cause it to expand and cool, and, if it contains enough moisture, results in clouds being formed. The relation of clouds to weather was discussed by Dr. Charles F. Brooks in *Sky and Telescope* last month. Some clouds are "fair weather" clouds, associated with high-pressure areas, but the clouds and the sequence of clouds accompanying a low-pressure area are the most important weather signs in the sky. Dr. Brooks tells the complete cycle to be observed when a storm is approaching and passing the observer. By persistent watching of this cycle you can soon learn what kind of weather to expect at your place of observation; but to predict exactly how much rain will fall, or when it will begin and end, requires knowledge of upper-air conditions and of the progress of the storm in adjacent regions. Many amateur meteorologists know how to send up weather balloons, to interpret barometer readings, to take wet- and dry-bulb thermometer readings, and can thereby improve their weather predictions.

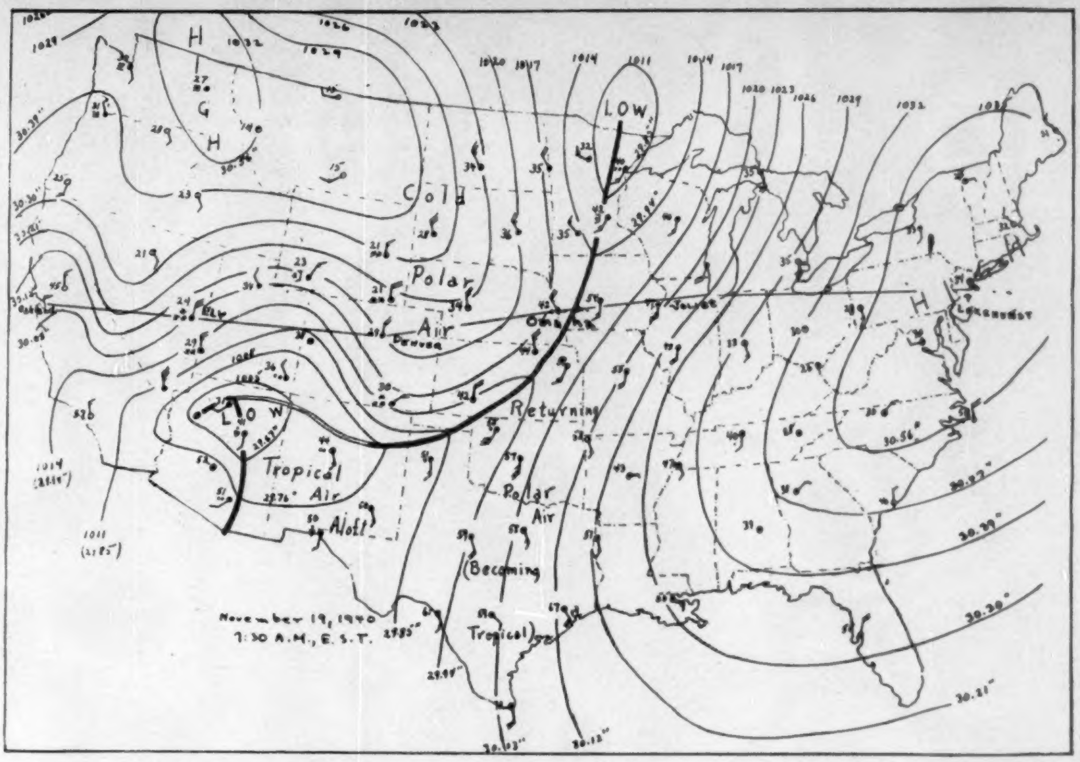
Amateur astronomers, too, learn to notice changes in the amount of moisture in the air, often the sign of cloudy weather to come, by changes in the quality of images of stars in their telescopes. Even the ancients noticed this change in starlight in moist skies, although we cannot accept literally the words of Aratus, in his *Prognostica* (270 B.C.):

A murky Manger with both stars
Shining unaltered is a sign of rain.
If while the northern Ass is dimmed
By vaporous shroud, he of the south gleam radiant
Expect a south wind; the vaporous shroud and radiance
Exchanging stars, harbinger Boreas.

He refers to Praesepe, the Manger or Beehive, the famous cluster in the constellation of Cancer, and to the stars γ and δ Cancri, sometimes called the Northern and Southern Asses. The absence of the Beehive in an otherwise clear sky is supposed to have been a sign of a violent storm.

Most weather maxims are not to be

Observe, on this weather map, how the surface winds circulate counter-clockwise around low-pressure areas; also the cloudiness in such areas. See The SKY, March, 1941, for a more advanced article on "Modern Weather Forecasting."



taken seriously, especially those which relate to weather on a certain date, such as "groundhog day" and St. Swithin's Day. Of course, "An east wind brings rain," has its basis in the fact that winds blow into lows, and lows are storm centers; therefore, an east wind indicates a storm center to the west of you, which will probably move east to your location. However, it is also important to observe the change in the wind, which can indicate where the center of a storm is located. If the wind changes from east to northeast to north during a storm, finally settling in the northwest or west, the storm passed to the south of you. If the wind shifts from east to west via the south, the storm passed to your north.

The moon is a favorite object for predicting the weather, but few phenomena connected with the moon make reliable weather forecasters. There is an old saying that the weather changes when the moon changes. That statement really has no meaning. The moon is always changing, and so is the weather, for that matter. In almanacs, the moon is shown as having four phases, but the change from one to the next is not sudden, but gradual. Only when the old moon disappears for a few days, to reappear after sunset as a narrow crescent, may we think of a real change. This period is sometimes known as the "dark of the moon" and is supposed to influence the growth of seeds planted during it. So far as is known there is no scientific basis for this notion, and yet I have had people tell me that in their long experience in growing things the phases of the moon are an important factor.

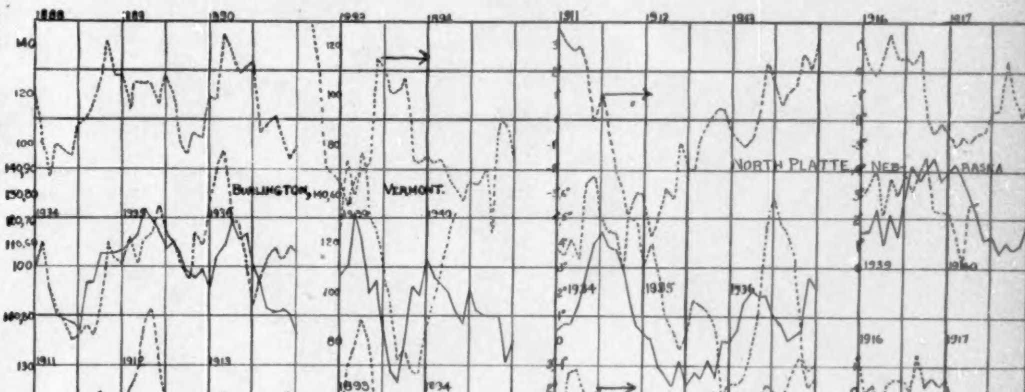
The direction in which the horns of the moon point, in relation to the horizon, is supposed to tell the state of the weather. The moon is "wet" or "dry," according to whether or not its cusps will hold water. The fact is that the horns always point away from the sun; their relation to the horizon depends on the season and the latitude of the observer.

The halo that is frequently seen around the moon, and around the sun, too, for that matter, is a more reliable weather sign. High above the earth the winds blow the tops off coming storm clouds. These winds, having greater velocity than those at lower levels, blow ahead of the storm the cirrus clouds which cause halos. At these high altitudes, the temperature is so low that the clouds are formed of ice crystals. Such clouds may be practically invisible, yet the moon's light shining through is refracted in such a way that a ring is formed. Longfellow says:

For I fear a hurricane.
Last night the moon had a golden ring
And tonight no moon we see.

Another old proverb, without basis, but illustrative of the simplicity of ancient weather prediction, also relates to halos: "Bigger the ring, the nearer the wet."

Coronas are often mistaken for halos.



Predictions of weather based on the 23-year cycle of solar activity. Note the similarity of the observed (dotted) curves at intervals of 23 and 46 years. Engraving from "An Important Weather Element Hitherto Generally Disregarded," by C. G. Abbot, Smithsonian *Miscellaneous Collections,* Vol. 101, No. 5, 1941.

They are smaller, close to the sun or moon, and frequently colored. They are not caused by ice crystals, but by mist or droplets of water. The size of a corona, unlike that of a halo, is not fixed. The smaller the drops, the larger the corona. Therefore, if the corona tends to grow smaller, the drops are increasing in size and tell of coming rain. On the other hand, if the corona appears to grow in size, clearing may be expected. This rule is subject to exceptions, of course.

Halos and coronas appear more frequently than most people imagine. For instance, in January, 1942, the U. S. Weather Bureau in New York reported three solar halos and two lunar. Many such phenomena go unnoticed, but an unusually striking halo will bring inquiries from the general public in great number. Knowing the frequency of weather signs is important in their interpretation.

"Single observer forecasting" (to speak in meteorologist language) requires careful observation of weather signs in the sky, and even the application of weather maxims and lore, when scientifically sound. Weather signs are, in a general way, reliable for the prediction of bad weather—good weather hardly needs foretelling.

A.A.S. TO MEET IN JUNE

Upon the invitation of Yale University, the American Astronomical Society will hold its 68th meeting at New Haven, Conn., June 12-14, 1942. This will take the place of the customary fall meeting of the society.

Headquarters for registration will be at the Sterling Law Buildings of Yale University. The meetings of the society will be held in this hall, and a large lounge will be available for the use of members.

The tentative program includes: *Friday morning*, teachers conference, council meeting; *afternoon*, opening general session, session for papers, tea; *evening*, lecture. *Saturday morning*, session for papers, business meeting, society photograph; *afternoon*, session for papers, tour of university buildings; *evening*, society dinner. *Sunday morning*, session for papers (if necessary); *noon*, lunch at the observatory; *afternoon*, excursion to Van Vleck Observatory, Middletown.

Election of officers will be held at this meeting. Titles of papers must be in the hands of the secretary, Dr. Dean B. McLaughlin, by May 18th, in order to be included in the printed program of the meeting.

THE GALACTIC POLE

A letter, dated January 27, 1942, from Prof. J. H. Oort, of the University of Leiden, Holland, contains a report about a recent determination of the pole of the Milky Way by one of his students, van Tulder. The position of the galactic equator was found from all types of objects showing strong galactic concentration, such as c stars, *O* and *B* stars, Cepheids, and galactic clusters. The position of the new pole is right ascension 190°.8, declination +27°.6, the mean error of the derived position being as small as ± 0°.2. The sun is found to be located 50 light-years north of the galactic plane.

The new values are concordant with those generally accepted. Following a vote of the 1932 convention of the International Astronomical Union, astronomers have generally used the "Harvard pole" at $\alpha \pm 190°$, $\delta = +28°$, as the standard one. This particular pole has been used as a basis for the extension tables of galactic coordinates published by John Ohlsson, of Lund, in 1932. The new study shows that the continued use of the Harvard pole is justified.

Dr. Oort mentions that the objects discussed in groups, at distances less than 2,500 light-years, between 2,500 and 5,000, and beyond 5,000 light-years, all gave closely agreeing values for the position of the pole and the height of the sun above the galactic plane.

BART J. BOK

A.A.V.S.O. SPRING MEETING

On invitation of Hunter College, the 31st annual spring meeting of the American Association of Variable Star Observers will be held in New York City, the weekend of May 30th. The main session will take place at downtown Hunter College on Saturday, the 30th, with the banquet that evening. Because of difficulties due to the war, the meeting was transferred from Pittsburgh, where it was originally scheduled.

RAINBOWS

On January 27, 1942, I think we had the most beautiful rainbow that I have ever seen. Both the secondary and primary were complete bows from horizon to horizon. The primary was very bright, especially near the horizon, and was so bright on the under side that the clouds looked like a searchlight was being played on them. The secondary was quite bright for its full length.

At 1:45 a.m., January 28th, W. F. Metzger, a locomotive engineer on the Western Pacific R.R. pulling train No. 12 out of Stockton, Cal., observed a lunar rainbow which, he said, was perfect and quite bright. He was very much interested because it was the first night rainbow that he had ever seen. He made a note of the particulars so he could tell me about it.

C. M. GINTER
Oroville, Cal.

Ed. Note: On March 9th, at Arlington, Mass., as this letter was being copied for publication, the editors observed a most spectacular rainbow. Mr. Ginter's description would apply equally well in this instance; in addition, brilliant supernumerary bows were visible inside the primary, and its violet-blue-green portions were unusually prominent. The sky between the bows was very dark; the secondary of surpassing breadth and clarity. (See "What Makes Rainbows?", The SKY, June and July, 1941.)

The third of the photographs of the eclipse of the moon taken at Creighton University Observatory on March 2nd.

LUNAR ECLIPSE OBSERVED

In the April issue of *Sky and Telescope*, "The Editors Note" that the lunar eclipse of March 2nd was a failure in the eastern United States because of thick clouds. We of the Middle West were more fortunate. Though the skies were overcast for several days preceding March 2nd, the day itself was clear and cool, with very little movement in the atmosphere. Moonrise did not occur here at Omaha until near the middle of the eclipse. Hence the early phases could not be observed, but comment on the beauty of the later phases was almost universal. The local newspaper reported the next morning that scores of people who missed the news reports foretelling the eclipse called up to inquire about the moon's unusual behavior. "What are the Japs doing to the moon?" inquired one caller. "There's blood on the moon," reported another.

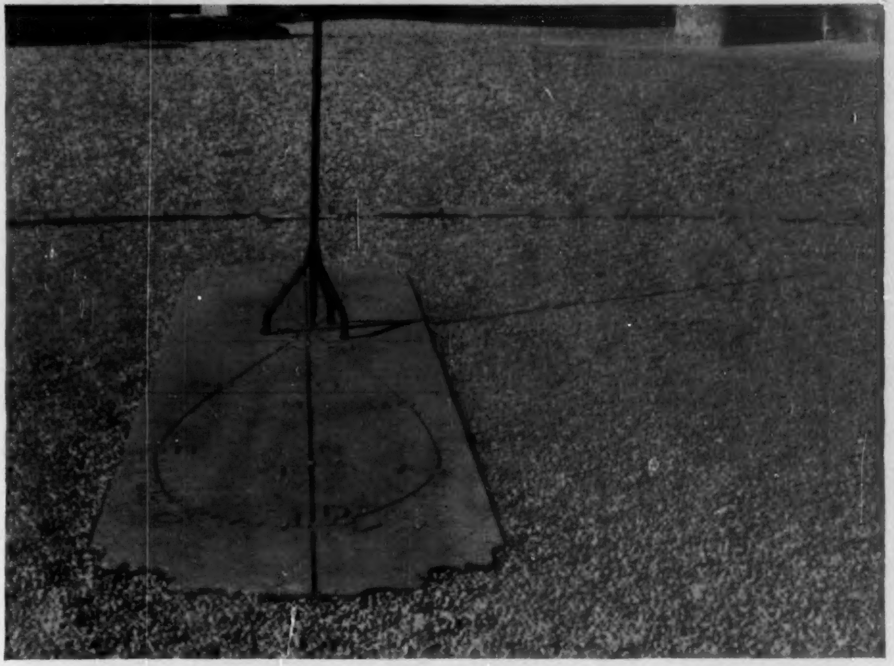
A little group gathered at the Creighton University Observatory to view the eclipse. The observatory has not been used much during the past five or ten years. Hence observations of scientific value could not be made at the time, though we hope to be able to do so before long. One of the group rigged up a plateholder, which we slipped over the low-power eyepiece of the 5-inch refractor. Using an Eastman Plus-X film pack, we secured the enclosed three photographs—two taken shortly after the moon left the umbra and one towards the middle of this phase. The first two are slightly out of focus. No filter of any kind was used, the exposure of the first two being about 12 seconds, of the third about eight seconds. I observed the occultation of 59 Leonis, but could not record the time, since our chronograph was not then in working order. We did not identify the comet 1942a, probably because of our lack of experience.

RAYMOND J. STRANGE, S.J.
The Creighton University
Omaha, Neb.

THE ANALEMMA

By Erwin Raisz
Harvard University

With the kind permission of The Journal of Geography, *this article is adapted from its issue of March, 1941, and covers a subject on which there is very little literature. All line-engravings are lent by* The Journal of Geography.



By means of the analemma, this sundial at Bourg, France, tells mean time. The perpendicular gnomon is set each day over the corresponding points on the analemma, and its shadow then indicates true local mean time on the marble band, which is marked into hours. Photo by R. W. Taylor, from *Sundials*, by Mayall and Mayall, courtesy, Hale, Cushman and Flint.

On many terrestrial globes we find a curious 8-shaped diagram placed somewhere over the empty blue of the Pacific Ocean, which is likely to induce some people to ask inconvenient questions. This device is called an analemma, and the questions raised about it need not be inconvenient, because its principle can easily be understood and it can be used as a key to open up some chapters of mathematical geography.

Definition. The analemma as applied to globes is a line which connects the points on the earth's surface where the sun is directly overhead on each day of the year when the local time is 12 o'clock on the meridian upon which the analemma is centered. Identical analemmas can be drawn on any meridian.

The North-South Motion. The migration of the location of the vertical rays of the sun is dependent on two major causes. The north-south component of the analemma is due to the declination of the sun. The sun is directly overhead at noon of June 21st on the Tropic of Cancer; it will be on the equator at the time of the September and March equinoxes, and on December 21st it will be on the Tropic of Capricorn. This variation is due to the inclination of the earth's axis to the plane of its revolution, or the ecliptic. The up and down migration of the vertical rays of the noonday sun is not even along the meridian; it will travel slower near the tropics and faster near the equator, as shown in Figure 1.

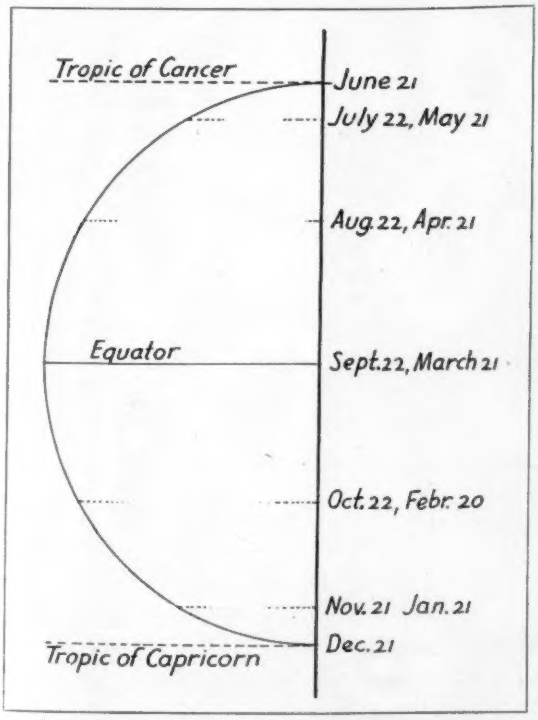


Fig. 1. The vertical rays of the noonday sun migrate up and down the meridian at an unequal rate.

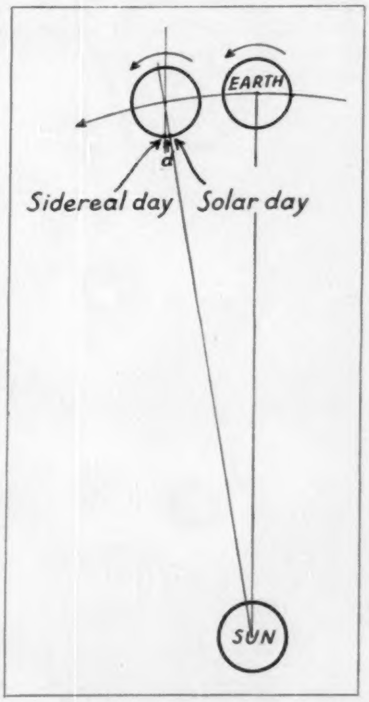


Fig. 2. The time interval between two noons (solar day) takes about four minutes more than a complete earth rotation (sidereal day).

The east-west component of the analemma is due to the equation of time—the difference between true solar time and mean solar time, more commonly called local time, or to put it simply, the difference between the clock and the sun. To understand this difference we have to consider certain facts about the motions of the earth and the various time measurements dependent on them.

Sidereal Time. Our measurement of time is based on the fact that the earth turns around its axis with a uniform speed. The time of one complete revolution, that is, from the time a star is exactly south of us until we see it exactly south again, is a sidereal day—the time unit used by astronomers. All sidereal days are equally long and last about 23 hours and 56 minutes of ordinary time.

Solar Time. As our life is regulated by the position of the sun and not the stars, the original basis of our time measurement is the solar day, the interval between two noons. As the earth rotates counterclockwise looking down at the north pole and revolves around the sun also counterclockwise, it obviously takes longer to reach the next noon than a sidereal day, as seen in Figure 2. The difference "d" is about four minutes of time.

Mean Solar Time, or Local Time. If the earth's axis were perpendicular to the

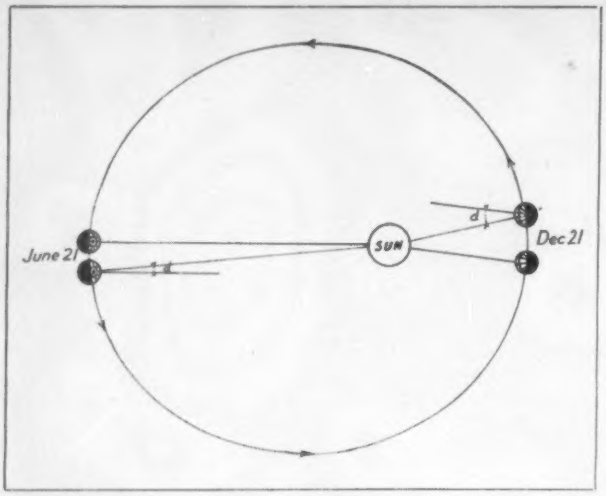


Fig. 3. The earth moves fast in December and slow in June, thus "d," and with it the solar day, is the longest in December.

ecliptic, and the earth would revolve around the sun with even speed on a circular path, all solar days would be equal. This is the kind of time which our clocks were showing before the introduction of the standard-time system; and it is called mean solar time by astronomers or, commonly, local time.

True Solar Time. Our previous assumption, however, is not true. The earth's axis is not perpendicular, but oblique to the ecliptic, and the earth does not move with even speed on a circular path, but the orbit of the earth is an ellipse with the sun at one of its focal points, and its speed varies so that the line connecting the earth and the sun sweeps over equal areas in equal time intervals. To do that, the earth has to move faster in January than in July. It takes a longer time also to make up for a larger distance "d" of Figure 2 in January than it does in July. At the time of the September and March equinoxes there is on this account no difference.

There is also another reason which makes the solar days vary through the year, and this is the inclination of the earth's axis. Let us assume again that the earth goes around the sun with uniform velocity, and "d" of Figure 2 is the same all year. In the September and March position, the earth has to rotate only the angle "α" to bring about the distance "d" required by the earth's progress along its orbit, thus at the time of the equinoxes the solar days will be shorter. In December or June the difference "d" has to be made up by a longer rotation, as shown in Figure 4. Thus the true solar day is shorter in March than the mean, and longer in July; again shorter in September and longer in December. The variation of the length of the true solar day due to both causes is shown in Figure 5A.

Equation of Time. The variation in the length of a single true solar day is not large; it can be expressed in seconds. The difference, however, accumulates day by day and reaches several minutes, as shown in Figure 5B. The two effects sometimes add up and sometimes counteract each other and their sum is the equation of time, the difference between the mean solar time, as shown by a watch (registering local time) and true solar time. Thus the sun is in noon position at 11h 43m 39s of local time on November 2nd.

The Analemma. If we apply the values of the equation of time as east-west components to Figure 1, we arrive at the 8-shaped figure of the analemma as we see it on globes (Figure 6). As the vertical rays of the sun travel 15 degrees in one hour, or one degree in four minutes of time, our horizontal scale is given. The earth rotates from west to east; thus when the sun is slower than the clock, the sun will be overhead to the west of the meridian at the time of local noon, and vice versa. This is true on any meridian, and the fact that the analemma is usually placed on the Pacific at the 120° W. meridian is only because here it interferes least with islands and continents. The analemma is incorrectly drawn on many globes. It should not be symmetrical on the two sides of the meridian.

The Uses of the Analemma. The analemma is far too crude a device to be used in navigation. It was used, however, for correcting the clocks in old times when each place had its own local time. This was done by observing the exact moment when the sun's center passed the north-south line (the meridian). By adding or subtracting the amount required by the equation of time, local time could be determined.

The analemma could also be used for calculating the length of the noonday shadow of a vertical rod or church steeple. From Figure 7:

$$\alpha = \phi - \beta \text{ and } \tan \alpha = \frac{s}{r}$$

$$\text{from which } s = r \tan \alpha$$

Reversing the problem, from the length of the shadow the latitude can be obtained:

$$\phi = \alpha \pm \beta$$

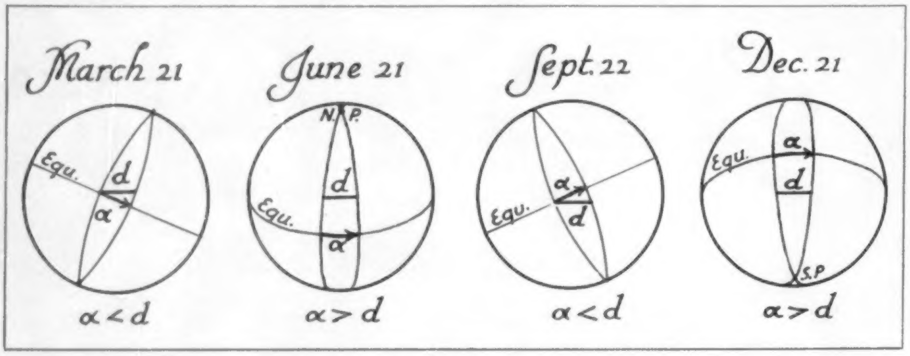


Fig. 4. The four cardinal positions of the earth as seen from the direction of the sun. It takes less additional rotation in March and September to make up for "d" (Fig. 2) than in June or December.

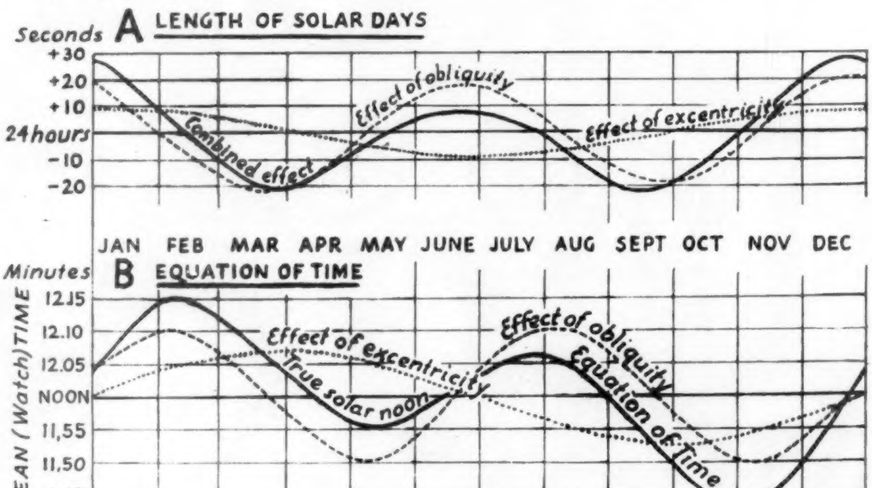


Fig. 5 A. The true solar day on December 21st is 26 seconds longer than 24 hours.
Fig. 5 B. Due to the cumulative effect of the variation in length of the true solar days, clocks lag behind true solar time by 16 minutes, 21 seconds, on November 2nd.

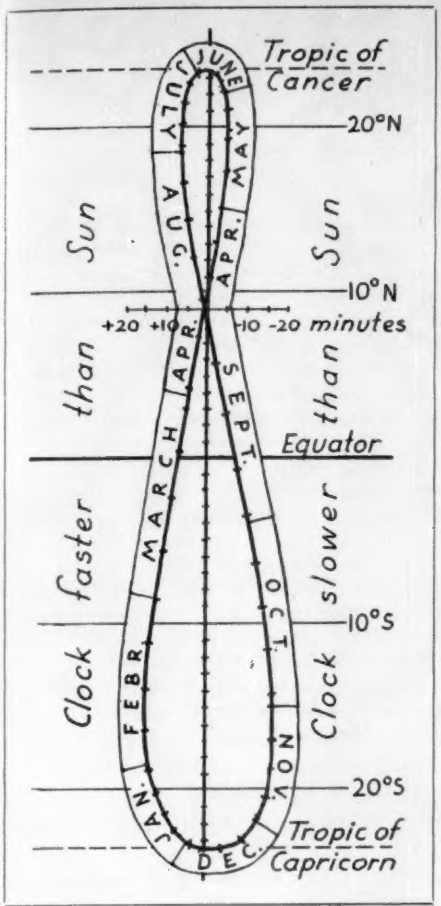


Fig. 6. The analemma on rectangular projection. Note that the line is not symmetrical on the two sides of the meridian.

α means the zenith distance of the sun and β the vertical component of the analemma in degrees measured from the equator. β has to be added in summer and subtracted in winter. At the time of the September and March equinoxes β will by zero.[1]

The analemma enables us to set up a globe at any day of the year at any hour exactly in the position in which the earth happens to be. By doing this at different hours and at different seasons the progress of the day and the year can be most convincingly demonstrated:

(a) Copy the analemma from your globe preferably on transparent paper, and paste it over your own meridian with rubber cement so that it can be easily removed again.

(b) First, let us consider the situation at noontime. Place the globe where the sun shines on it, and tilt the globe's axis until it is parallel with the earth's axis. In Figure 8 the angle ϕ designates your latitude and L your location. In this position the earth's axis points directly to the celestial pole near the polar star. Turn the globe around its axis so that your meridian is N.-S. which will bring L exactly to the top of the globe. This makes the horizon of L horizontal and you have reproduced your own position at noontime.

(c) Stick a long needle perpendicularly in the analemma on the spot which indicates the day of the demonstration. If the position of the globe is correct the shadow of the needle will disappear exactly at the time of local noon.

The time of your local noon can be found by adding four minutes for every degree to your standard time if you are east of the standard meridian, and subtracting them if you are west of the standard meridian. Standard meridians are:

Eastern	Standard	Time	75° W
Central	"	"	90° W
Mountain	"	"	105° W
Pacific	"	"	120° W

(d) For any other hour of the day, place the analemma on the meridian east or west of your own, which is supposed to have the sun overhead, figuring 15 degrees of longitude for each hour. For instance, at 10:00 a.m. local time the analemma should be on the meridian 30° east of yours. Stick the needle in the proper date on the analemma, and if your figuring is right it should not cast any shadow. Forty minutes later the needle should be moved 10° westward to have no shadow. The moving of the needle can be repeated during the day to illustrate the apparent motion of the sun, assuming a stationary earth. This assumption was held to be true by nearly everybody until the time of Copernicus.

(e) Keep the globe in this position and darken the room. Hold a flashlight or lamp representing a stationary sun at considerable distance from the globe, so located that the shadow of the needle is reduced to zero. Turn the globe around its axis from west to east and notice that identical shadow conditions can be obtained as before by this new idea—which, as proven by other facts, is the true cause of the recurrence of day and night. This demonstration may help to accept the idea of a rotating earth and a "stationary" sun, so contrary to common-sense observation.

The demonstration of the progression of seasons involves the repetition of the previous setup at different months of the year.

[1]People unfamiliar with triangulation may use graphic construction as in Fig. 7.

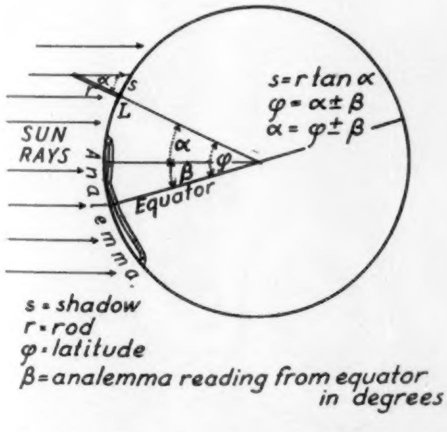


Fig. 7. Calculating the length of the noonday shadow of a rod.

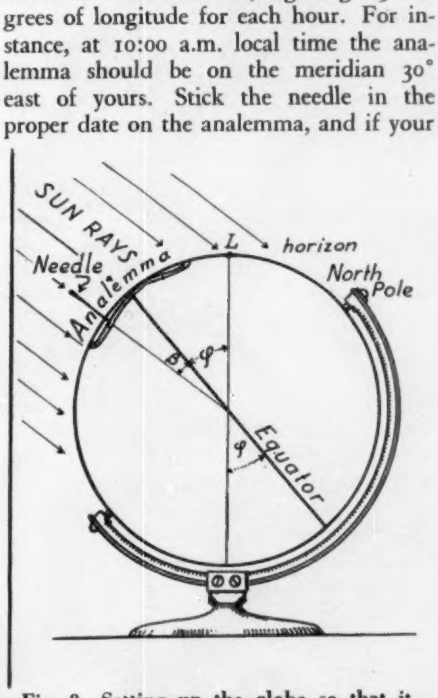


Fig. 8. Setting up the globe so that it will reproduce the actual position of the earth at a definite date and location.

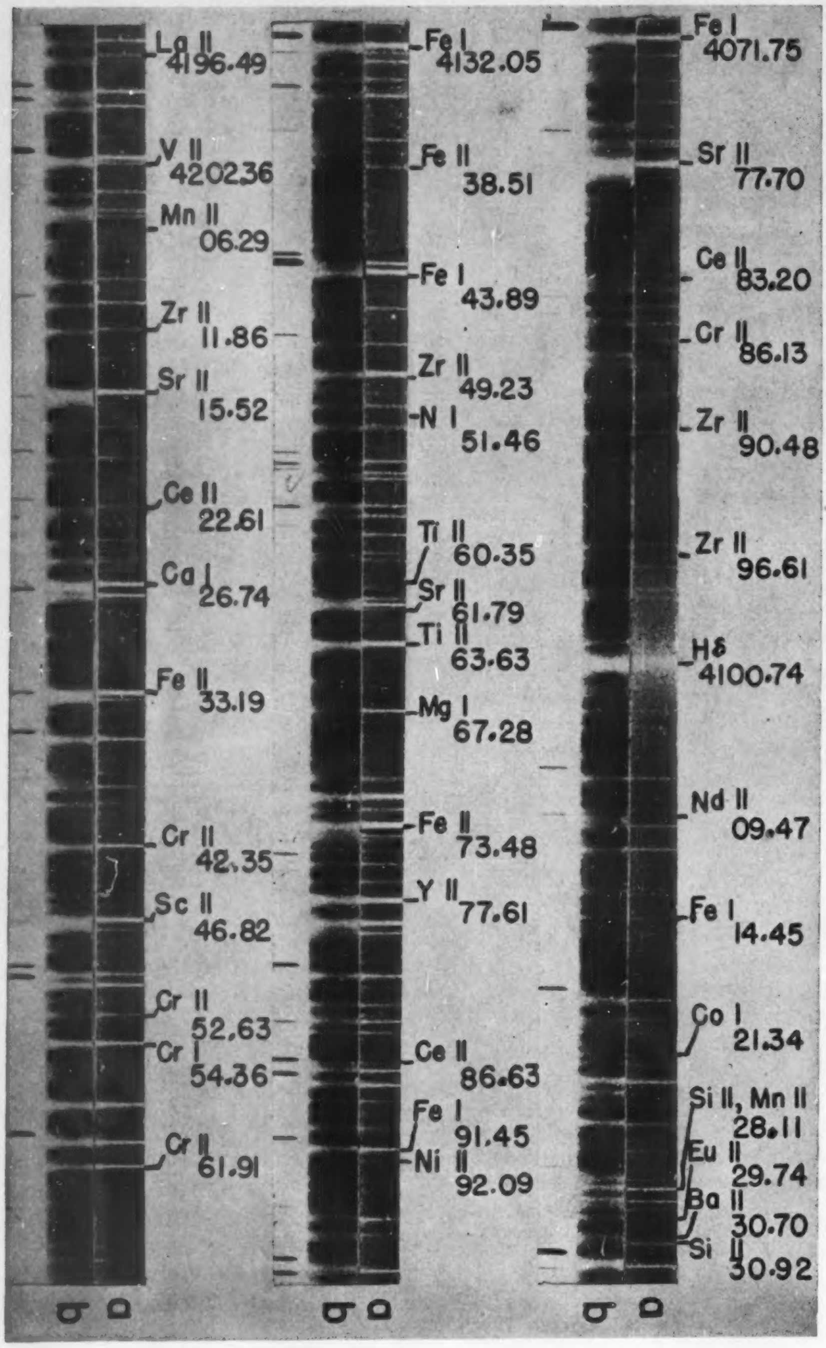
Letter to the Editor

. . . I enjoy the paper and always look forward to receiving it. I hope that when my next subscription becomes due we shall have more reason for optimism about the war position than we have at present. I think that Madagascar is going to play a large part in the future course of the war. If we cannot hold it, the Japs certainly will, and then, goodbye to our supply lines to the Middle East, India, and Russia.

. . . I think you would be doing good work if you could endeavour to impress upon those responsible for the training of our fighting forces, the advantage our boys would have if they are taught direction finding from the stars. My son is up in Libya and he writes that he had no difficulty in finding Polaris from the diagram which I gave him, and this, together with his knowledge of Orion, has given him the confident feeling that he will never be without aid in finding direction at night. I have heard queer stories from up there, showing how easy it is to become lost when only passing from one part of a camp to another.

One story is about airmen being lost in the air, deciding to crash-land and walk, then after walking for two days and completely giving themselves up for lost, they came across a track and had the good luck to be picked up by one of our lorries, when they found they had been *walking in circles* not far from a well-known place (Sidi Barrani). I asked what about their compass; my informant did not know, but said, compasses often go wrong anyway. I think you will agree that this could not have happened if the men had had only an elementary training in direction finding from the stars.

W. BACON
Benoni, South Africa



HIGH-DISPE

By J... L...

The spectra of α Carinae (Canopus) and of δ Canis Majoris (Wesen), taken with the coude spectrograph of the McDonald Observatory, Fort Davis, Tex. Canopus' spectrum, *a*, was made February 26, 1941; that of Wesen, *b*, January 22, 1941; enlargement is 7.6 times. The comparison spectrum is that of iron. Note how the radial motion has displaced the lines toward the red. The lines are sharp in Canopus, and considerably broader in Wesen—broadened in the supergiant atmosphere of the latter star by turbulent motion in the line of sight.

The Balmer line, Hδ, of hydrogen, is very much broader in α Carinae because of the higher pressure in that star (Stark effect). Lines of various elements are identified. Cerium, europium, neodymium, and yttrium are strengthened in δ Canis Majoris; lines of these rare elements are often a sign of high luminosity. All halftone engravings in this article are by courtesy of Yerkes and McDonald Observatories, and the *Astrophysical Journal*.

THE laboratory spectroscopists are busy and useful men, especially nowadays, when modern industry at war makes such extensive use of the methods and results of physical research. Some of them work in research laboratories, in steel plants and gasoline refineries, some in hospitals and even in police laboratories. They place a small sample, perhaps a sliver of steel, in an electric arc. In a few moments the spectrum of the vaporized metal is recorded on the photographic plate. The spectrograph used can have high dispersion, since the source is bright. An examination of the detailed record of the lines will reveal impurities present in the sample in infinitesimal amounts, will measure, perhaps, the strength of steel for a gun barrel.

But consider, then, the poor astronomer-spectroscopist. On a windy, cold night, he points his telescope at some distant speck of light. Setting the image of the star on the slit of his spectrograph, he begins his hours of patient guiding, letting the faint blob of light travel up and down the length of a slit 1/1,000 of an inch wide. His spectrograph must in general be of low dispersion, since he cannot spread the small available light over too long a section of the plate. Spectra of faint stars, even with great reflectors, may be only 1/10 of an inch long. Yet by an inspection of this tiny record, he can tell what elements are present and estimate the temperature and the pressure in the star's atmosphere. Recent advances in this type of research have been made possible by technical developments such as extremely fast plates and lenses, as well as Schmidt cameras. Careful attention to the minutest details of stellar spectra has resulted in a great increase in the accuracy of the classification of stars by spectral type and absolute magnitude.

I should like, however, to discuss another aspect of astronomical spectroscopy —in a sense, the easier one. Not all stars are faint, and with large telescopes we can sometimes afford the luxury of high dispersion, which allows us to see more detail in the spectra. Spectrograms nearly 40 feet long have been obtained of the sun; spectra four feet long, of many of the naked-eye stars, can be photographed. We can search for rare chemical elements in such spectra, make quantitative chemical and physical analyses of the star's atmosphere, and look at the detailed structure of the spectral lines. The spectrographs necessary for such studies are too large for even the giant reflectors to carry. They are therefore mounted in a fixed position in a constant-temperature room, and the light is reflected to them down the hollow polar axis of the telescope by an extra mirror. For once, the astronomer observes indoors, and warm, but out of sight of the sky.

Our first problem is the identification of the lines we see. The wave lengths can be measured accurately and compared with the lines of various elements observed in the laboratory. In matching laboratory and stellar lines, we must consider not only the coincidence of positions, but also the intensities of the lines and the presence of other lines of the same element. After careful search of the sun and other stars, about 60 of the 92 known elements have been identified, together with some of the isotopes. The missing elements are unidentifiable mainly because the astronomer is forever cut off from a large region of the spectrum; ozone in the upper atmos-

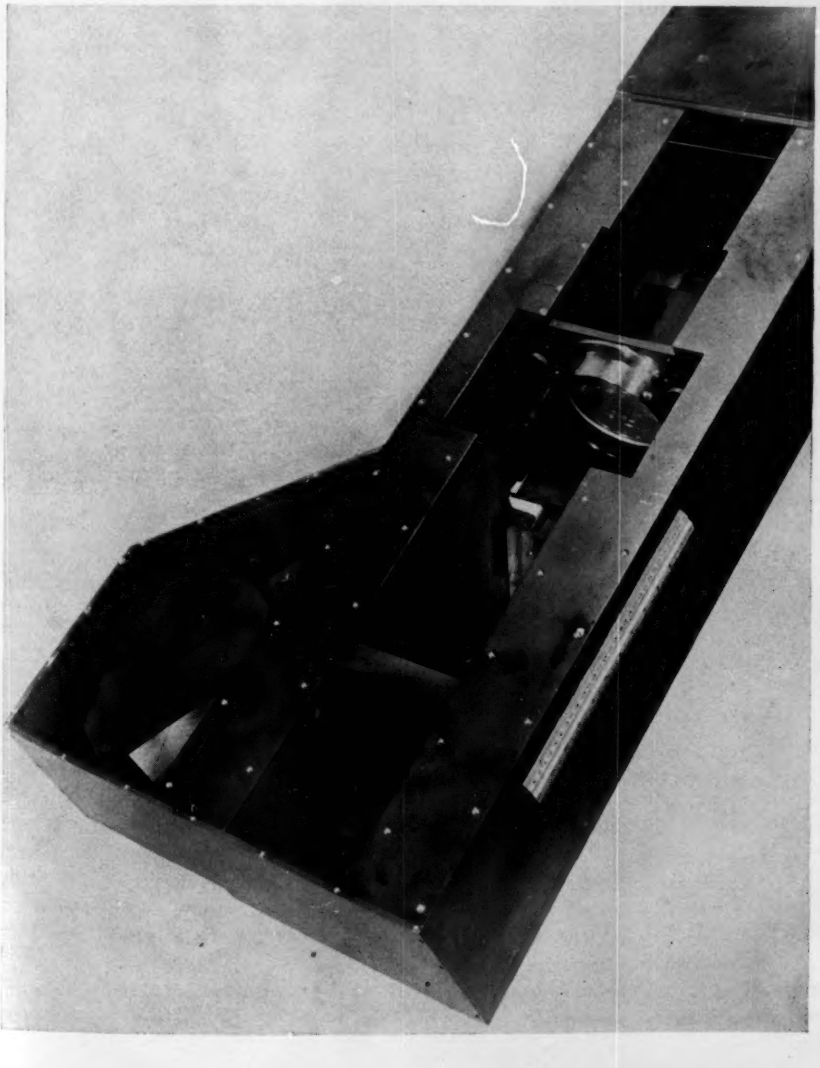
E SION SPECTRA

By Je L. Greenstein
Y s Observatory

phere prevents any ultraviolet sunlight of wave length less than 3000 A from reaching the earth's surface. Therefore, many fundamental questions may have to go unanswered until we can fly our observatories a hundred miles above the earth. Most of the absent elements are rare on the earth, and must be present in very small quantities in the stars. To reveal an element spectroscopically, the star's atmosphere must contain only 100 billion atoms per square inch. If this seems a large number, remember that there are a billion times as many atoms in a cubic inch of air!

When we someday make the final quantitative chemical analysis of the stars, we shall expect to find all the elements familiar on the earth. Certain differences between the stars and the earth, however, are already recognized. Hydrogen and helium are more common in the stars; they make up about 99.9 per cent of a star's atmosphere. It may be that hydrogen, the lightest gas, was lost into space from the earth when it was still hot.

Right: The 82-inch reflector of the McDonald Observatory. The coude spectrograph is in the room at the bottom of the polar axis.



Below: The coude spectrograph of the McDonald Observatory, with a foot-rule shown to give the scale. The second prism has its rear surface aluminized so that the light travels back through the prisms again on its way to the plate.

Deuterium (heavy hydrogen), lithium, and beryllium are known to be rare in the stars, and we have theoretical grounds for the suspicion that they would be quickly destroyed by the nuclear processes that maintain the star's flow of light. There are certain other abnormalities, such as stars with excessive amounts of helium, carbon, manganese, strontium, silicon, and europium. So far, however, there is no indication that any element exists in the stars which is not present in some form on the earth.

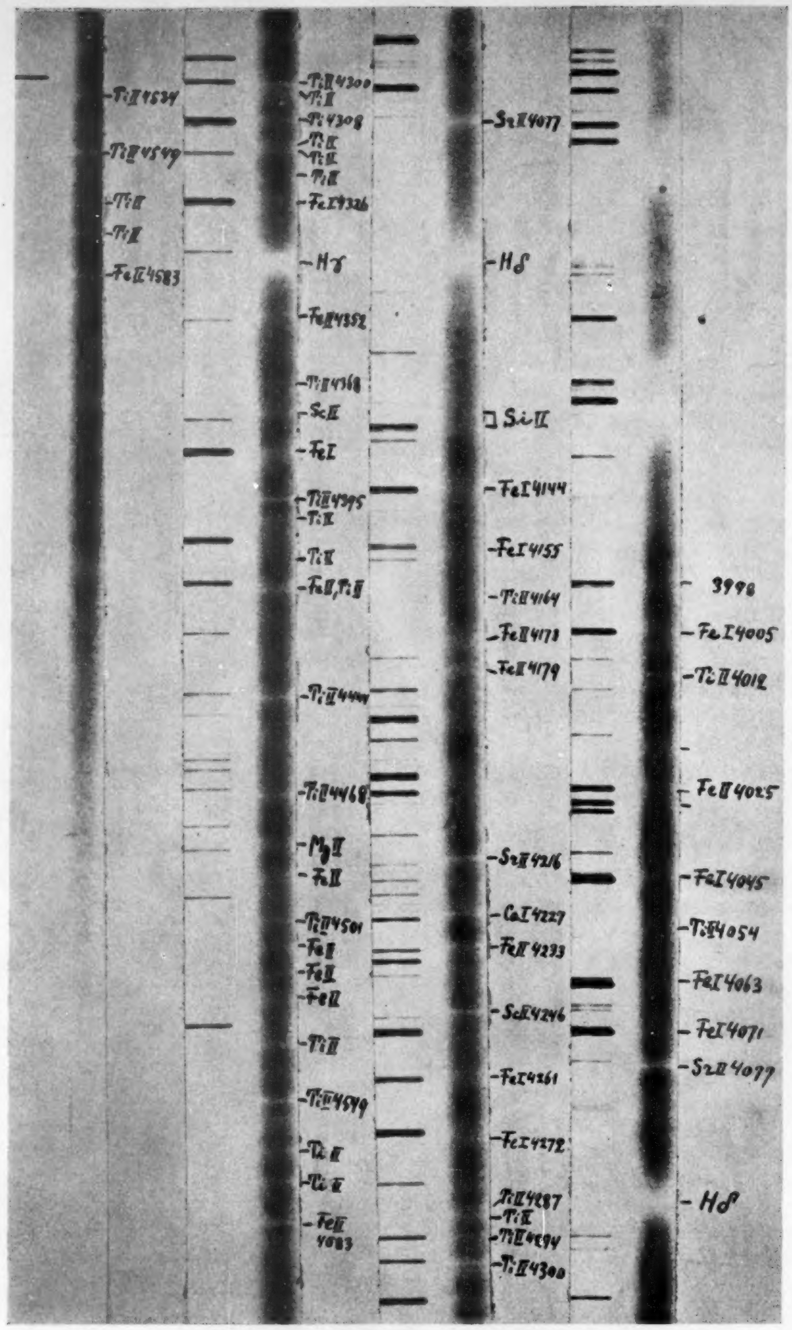
So much for chemistry. The study of the physics of the stars promises even more interesting results. Although the theoretical interpretation of stellar spectra is difficult, a few main principles lead to important conclusions. We are all familiar with the Doppler effect, in which radial motion to or from the observer displaces lines from their normal position in laboratory spectra. Besides the determination of the star's radial velocity from this Doppler shift, other applications are obvious.

For example, if a star rotates, we may consider that half of its disk is approaching, and half receding from us. Thus, half the spectral line is shifted to the violet, half to the red, and the line becomes widened. We can thus recognize from the shape of the line the existence of rapid rotation, and we find that some stars rotate 100 times as fast as the sun. A curious, unexplained phenomenon is the existence of rapid rotation among many hot stars, spectral types *B* and *A*, and its absence in the cooler stars of types *G*, *K*, and *M*,

that is, considering single stars only.

Many of the stars that have large rotations apparently become unstable and blow off part of their atmospheres into space. These expanding "shells" produce, by the Doppler effect, lines displaced to the violet of their normal positions. A very complicated case involving such effects is that of β Lyrae, that most puzzling of variable stars. (See *Sky and Telescope,* March, 1942.) Great currents of material circulate about one star of the pair under the tidal pull of the other. The sun produces currents in our oceans with speeds of a few miles per hour; in β Lyrae the enormous currents move with speeds up to 300 kilometers per second.

A very beautiful example of the phenomena occurring in shells is given by the star 14 Comae Berenices. The star itself has a spectrum resembling that of Altair, of spectral type *A*5, and with extremely rapid rotation. As a consequence, the lines are very broad and shallow. The rotation has apparently resulted in a nebulous cloud of gas, ejected by the star, and rotating relatively slowly about it. This shell produces certain lines present already in the star, as well as other lines not found in the star. The total spectrum observed then contains lines of nearly all grades of sharpness, seen in the accompanying illustration. The shell produces only weak lines of silicon and magnesium, so that these are particularly broad, coming only from the rapidly rotating star. It has strong lines of strontium, and these are almost completely sharp. From the reduction of rotational velocity indicated by such shell lines can be calculated the size of the shell, which is found to be 10 times as large as the star. 14 Comae is about twice the diameter of the sun, so the shell is considerably larger than the solar corona.



The spectrum of the shell star, 14 Comae Berenices, with moderate dispersion. The rapidly rotating reversing layer of the star produces the shallow broadened lines such as those of iron at 4045, magnesium at 4481, silicon at 4130. The shell lines are sharper, for example, strontium 4077 and 4216, scandium 4246, and titanium 4395 and 4549.

In normal stars, another consequence of Doppler shifts is seen in the shape of the absorption lines. Atoms in a gas move with speeds that increase with the temperature. The moving atoms absorb light at slightly different wave lengths, and the net result is a broadened line. In normal stars, this broadening may be used to estimate the temperature of the gas. In supergiants, the observed broadening is found much too large to be explained by these temperature-motions. Apparently, the surface of these stars is violently boiling or "turbulent." Perhaps, super-prominence activity, or super-granules,[1] is responsible —in fact, some lines are found to be double, indicating a flow of matter out into space.

The structure of a star's atmosphere is like that of the earth's. The density and pressure decrease outwards, and the temperature drops. Far beyond the normal limits of what we call the sun's reversing layer, we find the chromosphere and the corona. The rate of decrease of the pressure and the temperature should be predictable theoretically, but we find that many observational facts contradict the simple theories. The atmospheres of the stars seem to be too large, in general. The solar corona is an extreme example of such an extended stellar envelope. In the stars, direct observation of the separation of corona, chromosphere, and reversing layer, is impossible, but detailed study of high-dispersion spectra permits us to determine the levels in the atmosphere at which the various lines are produced.

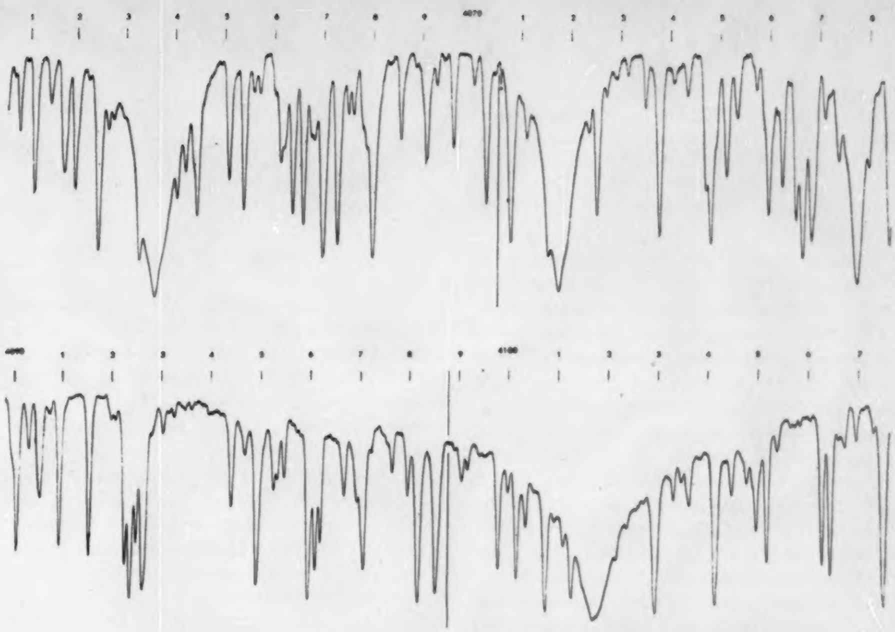
The spectra of long-period variables, stars of low temperature, provide a simple example. These stars show strong hydrogen emission lines, associated usually with high temperature. However, on high-dispersion spectra, some emission lines are found split into two or more components. The explanation is that some strong metallic absorption line, at the wave length of the hydrogen line, absorbs the hydrogen light on its way out of the star, thereby causing the emission line to appear split. Obviously, the hydrogen emission must be produced in a region where comparatively high temperature prevails, that is, below the reversing layer of the star. There are also strong bands of the molecule, titanium oxide. These titanium oxide bands also weaken some of the hydrogen lines. Apparently, we can see deep into these stars, and observe phenomena at many different levels of their atmospheres.

The shapes of the lines in high-disper-

[1] See "In Focus" on opposite page.

sion spectra provide another means of probing into the stars. The blackening of the photographic plate along the spectrum can be measured by the use of a microphotometer, an instrument which gives us an exact record of the actual shape of the line—its width, and its depth. These shapes are dependent on various physical processes going on in the star's atmosphere. The atoms can absorb radiation without disturbance in giant stars, where the pressure is low and the distance between atoms relatively large. In dwarfs, the pressure is higher, and collisions between atoms may become important. During a collision the atom absorbs at a different wave length than normally, and the line produced by many such atoms is greatly widened. The hydrogen atoms are particularly sensitive to near-collisions, in which the electrostatic attractions and repulsions of charged particles widen the line (Stark effect). The shapes of such lines are easily recognized, even with small dispersion, and the width of the Balmer lines has long been used as an excellent criterion of pressure, and therefore of absolute magnitude.

The physics of stellar atmospheres is still a new science. Larger telescopes, better photographic plates, more perfect lenses, are all contributing to the growth of observational knowledge. New facts, some imagination and theory, will take us far.



Reproduction of two sections of the Utrecht *Atlas of the Solar Spectrum*. These are microphotometer tracings of the sun's spectrum taken with the highest dispersion. The wave lengths are given above each tracing. The intensity of the line is given by the drop from the continuous background at the top of the tracing. Note that the majority of the lines are very sharp, since the sun rotates slowly, and atoms move slowly at the solar temperature.

The strong lines at 4063 and 4072 are due to iron. They are broadened in part by collision effects in the "dwarf" atmosphere of the sun. The line of hydrogen, centered at 4102, has been broadened by the Stark effect. Notice that it has extensions on both sides that are shallow, but extremely broad compared to the "wings" of the iron lines.

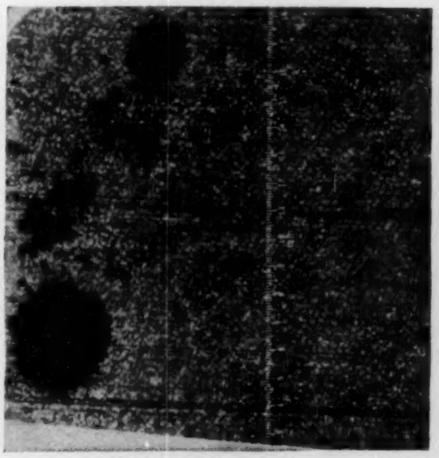
In Focus

IN his article on the high-dispersion spectra of stars, Dr. Greenstein mentions turbulence in stellar atmospheres as possibly giving evidence of "supergranules." Under good seeing conditions, the sun's surface presents the appearance of a rapidly boiling fluid. The rising currents of hot gas appear bright. They are called granules, or "rice-grains," are several hundred miles in diameter, and last only two or three minutes.

The back-cover photograph this month is intended to show both a close-up of a large sunspot group and details of the solar granules. It was taken July 10, 1937, by Dr. Philip C. Keenan, of Yerkes Observatory, using the 40-inch refractor. In his paper on "Dimensions of the Solar Granules," in the *Astrophysical Journal*, 88, 363, from which the small illustration shown here is taken, Dr. Keenan says:

"Measurements have been made on several negatives taken recently through the 40-inch objective, diaphragmed to small apertures, at moments when the air was steady enough to give unusually good definition. The exposures were made on plates coated with Eastman Kodalith emulsion, type Va-G. . . . It is due primarily to their high contrast and extremely fine grain (the diameter of the developed plate grains was estimated at 0.3 μ under a magnifying power of 2300) that these plates were better suited for measurement than those taken here in past years under equally good observing conditions.

"The exposures were made through various combinations of green and yellow filters, which, together with the sensitivity-curve of the panchromatic emulsion, confined between 5200 and 5800 A the spectral region employed. Throughout this range, the focal curve of the telescope is nearly flat, and the effective wave length may be taken as 5550 A. . . . At the visual focus, 1 mm. corresponds to 10″.66. The . . . streaks in the picture are due to



This is a portion of the same Yerkes Observatory photograph from which the back cover is taken. A scale in millimeters is shown.

specks on the filters, which were carried on the moving slit of the focal-plane shutter.

"On the reproduction it is easy to distinguish the areas of good definition from the streaks and spots where the solar details are blurred by convection currents in our atmosphere. . . ."

Dr. Keenan estimates the granules ordinarily observed have a size of from one to two seconds of arc. Since the sun's geocentric parallax is about 8″.8, and the earth's radius 3,960 miles, one second corresponds to 450 miles. The largest granules probably reach about 1,350 miles, but their size changes extremely rapidly. Between the bright granules, which number some 2,600,000 on the entire sun at one time, the average distance is about 900 miles, but this space is not of uniform darkness. It probably contains granules which are forming and others which are disintegrating. Perhaps it is well to repeat here that sunspots are "dark" by contrast only—in similar fashion, the background on which the granules are seen is really very bright.

LYOT HONORED BY FRANKLIN INSTITUTE

The invention of the coronagraph, with which the solar corona has been observed without the aid of a total eclipse, has earned for Dr. Bernard Lyot, of Meudon Observatory, Paris, France, the Howard N. Potts medal of The Franklin Institute.

Amateur Astronomers

Fourth National Convention Postponed

THE following letter, dated April 16, 1942, has been received by the chairman of the Committee on Permanent Organization:

When our letter which appeared in the April issue of *Sky and Telescope* was written we felt that, in spite of rapidly changing conditions, we could arrange a successful meeting July 4th and 5th in Detroit. Since then the picture has become increasingly difficult, from our point of view.

At the April meeting of the Northwest Astronomical Society, and that of the Detroit Astronomical Society, the Amateur Astronomers Convention, scheduled for the above dates, was the subject of considerable discussion. As the former society held its meeting earlier in the month, the suggestions and thoughts of its members were given attention at the Detroit Astronomical Society's meeting on April 12th.

While great interest was displayed by the members of the two local groups in the 1942 National Convention, it was felt that the prospects for adequate attendance were growing daily blacker, owing to restricted transportation and other phases of life under war conditions—to such an extent that holding the convention here as originally planned might work to the embarrassment and disadvantage of the national organization. Our members believe so many amateurs would be prevented from coming that the actual registration would not warrant our asking the various speakers, and institutions which were granting us the use of their facilities, to expend the time and labor involved in the successful operation of the convention.

The United States Government has taken over the McMath-Hulbert Solar Observatory at Lake Angelus and we have been notified that it will be closed to visitors indefinitely. This institution was founded and developed by amateurs and a visit there was to have been one of the main features of the convention.

Greenfield Village at Dearborn, always a highlight in the visits of tourists to Detroit, is closed and we are unable to ascertain if it will be open at all this summer. Owing to the conversion of the factories to war industries it will be impossible to show visitors any of the automobile plants. The operation of pleasure craft along the Detroit River has been curtailed, partly due to the proximity of great defense plants, and this curtailment may be augmented. The area of metropolitan Detroit is engaged night and day in defense activities which have increased the working hours of both men and women. These conditions were unforeseen July 4, 1941, when the invitation was extended to the Third National Convention of Amateur Astronomers at Washington, D. C. All this restricts our plans for a successful convention and for the entertainment of guests.

We understand that the University of Michigan has withdrawn its invitation to the American Association for the Advancement of Science to hold its usual June meeting at Ann Arbor, and, as a result, that society has cancelled its 1942 summer meeting. We are further informed that the National Academy of Sciences is holding only a business meeting this summer and is having no scientific sessions.

At the April 12th meeting of the Detroit Astronomical Society a motion was carried that if the 11 societies at present considering final ratification of the by-laws of the Amateur Astronomers League of America consider it desirable to have a policy-making group meet in Detroit, July 4th and 5th, to carry on the necessary business of the A.A.L.A., it would be glad to cooperate. The Northwest Astronomical Society concurs in this.

Under the circumstances, and not knowing what further restrictions may be in force by the summer, we, as presidents of our respective societies, feel it wise to withdraw, temporarily, our invitation to the National Convention to assemble in Detroit. The withdrawal is made with regret and it is not to be construed as evidence of lack of interest on the part of members of the local organizations. The invitation will be extended again, as soon as conditions permit. We sincerely hope that the next National Convention of Amateur Astronomers will be held in Detroit, when conditions for its success and for the entertainment of guests will be more easily met.

If the 11 societies mentioned, and other interested groups, wish to hold a meeting of delegates in Detroit, July 4th and 5th, for the purpose of carrying on the plans of the A.A.L.A., the societies we represent will be glad to cooperate to the fullest extent in making such a meeting a success, and as pleasant as conditions permit.

In making our decision we are considering only the interests of the National Convention of Amateur Astronomers and are very sorry that the pleasure of acting as its hosts is being deferred.

C. W. SPAIN, president
Detroit Astronomical Society

A. J. WALRATH, president
Northwest Astronomical Society

The amateur and professional astronomers of several cities in Michigan are to be warmly thanked for their unstinting efforts to carry out and support the original convention plans.

Meanwhile, in the absence of action by the Washington convention which might cover this situation, it appears evident that the Fourth National Convention must be considered postponed. The redeeming feature is the possibility of holding an organization meeting of the Amateur Astronomers League of America in Detroit this summer. The 11 societies and all others considering membership in the League are invited to consider sending at least one delegate to such a meeting, and to communicate their recommendations to the undersigned.

CHARLES A. FEDERER, JR., chairman
Committee on Permanent Organization

AMATEUR ASTRONOMERS ASSOCIATION
New York City

Fifteenth Anniversary Dinner: The A.A.A. celebrated its 15th birthday with a successful dinner at the Hotel Brewster on April 1st. Speakers were: Dr. Clyde Fisher, first president; Dr. Clement S. Brainin, president; Dr. Peter van de Kamp, director of Sproul Observatory; Dr. Lyman Spitzer, Jr., Yale University; and Dr. Jan Schilt, director of Rutherfurd Observatory.

Motions in the Solar System is the subject of the lecture by James B. Rothschild, advisor of the Junior Astronomy Club, on May 6th.

Annual Meeting: The regular Annual Meeting will be held on May 20th. Committee reports will be presented and other affairs of the society discussed. A feature of the meeting, after its business portion, will be the showing of astronomical motion pictures.

Annual Field Trip: May 30-31, to Harvard College Observatory. All interested persons should communicate with the secretary, George V. Plachy.

ANSWERS TO DO YOU KNOW?
(*Questions on page 6*)

I. 1, d; 2, b; 3, a; 4, d; 5, d*; 6, a; 7, b; 8, d; 9, b; 10, d.

II. 1, Taurus; 2, Vulpecula; 3, Andromeda; 4, Orion; 5, Cygnus; 6, Lyra; 7, Doradus; 8, Sagittarius; 9, Cygnus; 10, Canes Venatici.

III. A. Spectroheliogram. A photograph in hydrogen light of a bi-polar sunspot group. Note the bright hydrogen flocculi between the spots. Mt. Wilson photo.

B. Eruptive prominence. Observe how rapidly it rises and falls on the sun's surface. McMath-Hulbert photo.

C. Saturn. The dark portion between the bright and the outer rings is called Cassini's division.

D. Nova Persei, 1901. The nebulous region surrounding the star after outburst was observed to be rapidly expanding. Yerkes photo.

E. The aurora borealis or northern lights. Photo by Carl Stoermer.

F. William Cranch Bond (1789-1859). He was first director of Harvard College Observatory, and made the first photographs of the moon.

* Correction to Do You Know? March issue, page 17, question I, 6, should be: A millionth of a millimeter is indicated by the symbol $m\mu$.

BEGINNER'S PAGE

By Percy W. Witherell

Sunspots

SUNSPOTS have interested mankind even before the days of telescopes. Very large ones can sometimes be seen by the naked eye under favorable circumstances, such as through haze at sunset, fog, or escaping steam. Some 95 observations were recorded by the Chinese between A.D. 188 and 1638. The spots were picturesquely described as shaped like a bird, an apple, an egg, and a flying bird. Even after 1610, when the telescope disclosed the reality of the spots, the educated world generally refused to believe in anything that seemed to cast reflection on a perfect sun. In 807 and 1609, naked-eye spots were explained as transits of intervening bodies.

Schwabe began in 1626 a systematic watch of the sun's surface, which has been continued to the present time. Many important observatories have specially designed solar telescopes and keep a daily record of the condition of the sun. Laboratories have been established to cooperate with the cable, telegraph, telephone, and radio companies of the world, to compare the relative strength of their transmission services with the number and area of sunspots. The geodetic surveys of the variations in the magnetism of the earth and the observation of aurorae have also contributed data.

From these observations much information has been collected. The sun revolves from east to west in about four weeks as seen from the earth (synodic period); the axis of the sun is inclined 7° 10'.5 to the ecliptic (plane of the earth's orbit).

The average life of a group of sunspots is generally about a month. Only about seven per cent last through two rotations of the sun, and about three per cent for three or more trips. The longest-enduring sunspot on record, of 18 months, occurred in 1840-1841. An interesting phenomenon is the increasing speed of rotation of the spots as they near the equatorial region; the time of rotation of the sun decreases from 27½ days at latitude 40° to 24.65 days at latitude 0°. Incidentally, it takes over 33 days to rotate at latitude 75°.

The spots differ greatly in appearance, but are characterized by a dark central *umbra* surrounded by a *penumbra*, with a fringe of converging filaments. Spots are sometimes single, but more often there are two large and numerous small ones in the group. Usually, as they rotate with the sun's disk, the preceding spot is more evenly shaped and smaller than the following one.

The umbra may be 500 to 50,000 miles across, and the penumbra as much as 150,000 miles long. Sometimes in the course of a single day, a spot is seen to divide and separate.

The umbrae appear dark only because of the contrast with the intense light of the sun. Actually they are brighter than practically any terrestrial light. Photographed in yellow light, umbrae are 1/10 as luminous as the photosphere (surface of the sun). Mercury or Venus, when in transit across the sun, appear darker than any spot near which the planet passes.

Sunspots are surface appearances of deep-rooted magnetic cyclones in the sun's atmosphere. The chart shows how a new group appears in the 30° latitudes just before the earlier group disappears at about 5° latitude. It also shows how the preceding spot is of a different polarity than its companion; how they reverse their polarity at the beginning of each 11-year cycle; and also that the above conditions are reversed in the two hemispheres.

From one sunspot maximum to the next is the much-talked-about sunspot cycle of a little over 11 years. There are two cycles or about 23 years between the returns to the beginning of the same polarity at maximum. From 1645 to 1715 there was only one spot (1705) in the northern, and not many important ones in the southern hemisphere of the sun.

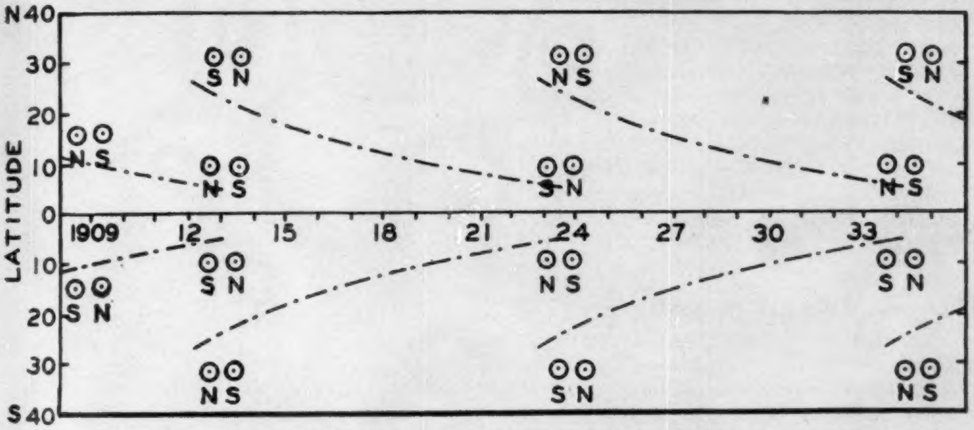
A short time after a large group of sunspots passes across the meridian of the sun which faces the earth, the magnetism of the earth is suddenly affected to the extent of disrupting all forms of electrical communication and sometimes producing brilliant auroral displays.

Solar flares of ultraviolet radiation occur at intervals which affect the ionized layer of the atmosphere to the extent of "blacking out" short-wave communications, but without making any visible appearance on the face of the sun.

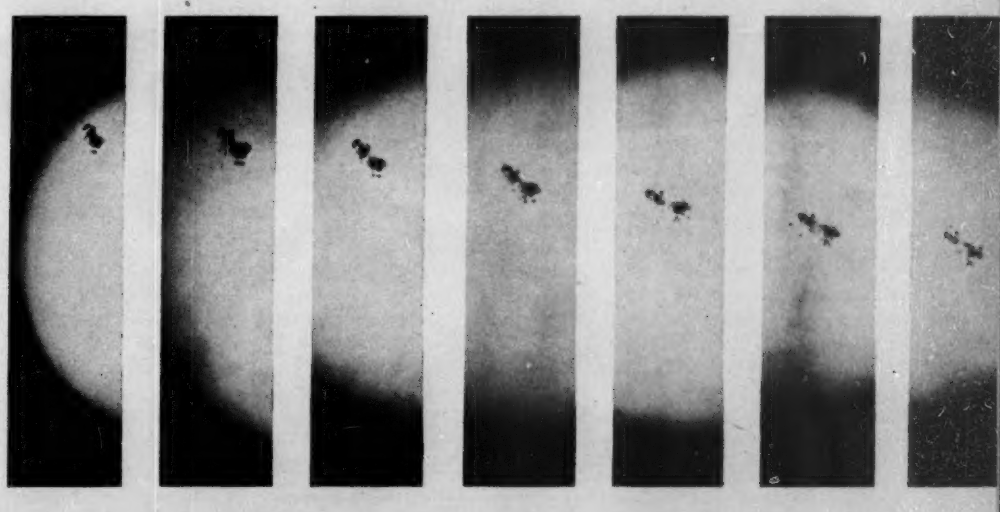
The total radiation of the sun varies with the sunspot cycle; the mean temperature of air at the earth's surface is lower when the spots are most numerous. Dr. A. E. Douglass has shown a correlation between the relative annual growth of tree rings with the sunspot cycle. (A diagram showing interesting correlation between sunspots and terrestrial activities appears on page 8.)

The last maximum was in 1937; at present the minimum is passing, and effects of the new maximum are due in the near future.

In addition to the above well-established investigations, various hypotheses have been studied as to possible connection between sunspot activity and the effect of magnetic and climatic changes on human behavior, but without any general acceptance of the theories.



This diagram of the law of sunspot polarity shows the approximate variation in mean latitude and the corresponding magnetic polarities of sunspots observed at Mt. Wilson from June, 1908, until January, 1935. The preceding spot is on the right in each case.



This sunspot group, taken by the Rev. Wm. M. Kearons, of Fall River, Mass., is one of the largest on record (10 times the surface area of the earth). The photographs show the rotation and changes during one week, October 7-13, 1938.

NEWS NOTES

By Dorrit Hoffleit

AGE OF THE SOLAR SYSTEM

More accurate measurements, recently made by W. J. Arrol, R. B. Jacobi, and F. A. Paneth on sample meteorites, indicate a considerable range in the helium content of iron meteorites and a remarkable constancy of uranium and thorium, the elements important in age-determinations. The highest ages derived from the helium content amount to 6,000 and 7,000 million years. If meteorites have been members of the solar system since their formation, these figures would imply an age of the system of at least 7,000 million years—much greater than the age of the oldest rocks in the terrestrial crust. An extrapolation from data regarding the "expanding universe" would allow only 2,000 million years as the age of the universe. Evidently mother nature is skillful in concealing her true age.

COMET AWARDS

The Donohoe Comet Medal is awarded annually by the Astronomical Society of the Pacific for the discovery of new comets. Eight medals were awarded for the independent discovery of four new comets in 1941. They go to men of five different countries: C. L. Friend and E. Reese, U.S., Comet 1941a; R. P. de Kock, H. van Gent, and M. du Toit, all of South Africa, for the discoveries of comets 1941c, d, and e; M. Howarth of New South Wales and M. Bernasconi of Italy for independent discoveries of 1941d; and G. Neujmin, U.S.S.R., for an independent discovery of 1941e.

Two other comets discovered in 1941 proved to be returns of periodic comets whose orbits were already known from previous visits (Comet Encke and Comet Schwassmann-Wachmann 1929I, rediscovered last year by G. Van Biesbroeck and H. M. Jeffers, respectively).

TULLIO LEVI-CIVITA

Nature reports the death on December 29th of Tullio Levi-Civita, age 68, professor of theoretical mechanics at the University of Rome from 1918 to 1938. The British journal pays him tribute by saying he was "unquestionably one of the best equipped and most versatile mathematicians of our time." Einstein's general theory of relativity had its foundations in a great treatise on tensor analysis by Ricci and Levi-Civita.

At the time of Harvard University's Tercentenary celebration in September, 1936, Levi-Civita, under the joint auspices of the American Mathematical Society and the American Astronomical Society, delivered a lecture on "The Relativistic Problem of Several Bodies." The same month he gave a series of lectures at the Rice Institute, Houston, Tex., the first being "A New Deal for the Elementary Foundations of Relativity."

Levi-Civita was the recipient of many honors, including honorary membership in most of the scientific academies of Germany and Italy. From all of these, except the Pontifical Academy of Sciences, he was expelled for racial reasons in 1938. In his native country his death was commemorated only by the Pontifical Academy, otherwise passing practically unnoticed.

JUNE SYMPOSIUM ON SPECTROSCOPY

The University of Chicago will be host for a symposium on spectroscopy, under the chairmanship of Prof. R. S. Mulliken, of the physics department, with sections for discussion in astronomy and chemistry. The astronomical sessions are to be held on Monday and Tuesday, June 22nd and 23rd, and are being planned by the astronomers of Yerkes Observatory. The spectra of comets, the spectra of planets, and the structure of the earth's atmosphere are the topics for the astronomical talks. It is expected that Dr. Andrew McKellar will come from Victoria to participate in the discussion of the first topic, together with Dr. P. Swings, of Yerkes, and Dr. N. T. Bobrovnikoff, of Perkins. Other speakers tentatively include Dr. Fred L. Whipple, of Harvard, and Dr. C. T. Elvey, of McDonald, for the session on the structure of the atmosphere, under chairmanship of Dr. Oliver R. Wulf.

Everyone interested in attending the symposium is invited to write Dr. Otto Struve, director of Yerkes Observatory, Williams Bay, Wis.

CAMILLE FLAMMARION

The British journal, *Nature*, commemorates the birth, on February 25, 1842, of the great French astronomer, Camille Flammarion. Probably no other astronomer of the past century has done more than Flammarion to popularize astronomy. His first book, *The Plurality of Inhabited Worlds*, was published when he was 20 years old. It was followed by *The Marvels of the Heavens, Popular Astronomy, The Planet Mars, Astronomy for Amateurs*, and many others. He was also the founder of the journal *L'Astronomie*, and of the Societe Astronomique de France. He died in 1925 at Juvisy-sur-Orge, a small chateau and park he had acquired through an admirer of his writings. His widow, herself an astronomer, still carries on much of his work.

MEDAL OF THE ROYAL ASTRONOMICAL SOCIETY

Dr. R. L. Waterfield, physician and one of Britain's most ardent amateur astronomers, author of *A Hundred Years of Astronomy*, has been awarded the Jackson-Gwilt Medal and Gift of the Royal Astronomical Society "for his general contributions to astronomy, and in particular for his photographic work on eclipses and comets and his visual observations of planets."

THE SPIRAL M33

Messier 33, a beautiful spiral galaxy in the constellation Triangulum, is the subject of nearly 50 pages of discussion in four papers (by Aller, Mayall and Aller, and Wyse and Mayall) of the January, 1942, issue of the *Astrophysical Journal*. Detailed studies of systems like M33 are important because they enable us to arrive at better interpretations of conditions in our own galaxy, which we cannot study from the outside.

From an analysis of radial velocities of emission objects, N. U. Mayall and L. H. Aller have studied the rotation of the spiral. They find the central part rotates almost like a solid body, the rotational velocity increasing fairly uniformly with distance from the center up to about 1,000 parsecs. Beyond that, to the apparent limit of the spiral, about 2,000 parsecs from the center, the rotational velocity is analogous to planetary motion, the velocity decreasing with distance outward. Comparing velocities in M33 with corresponding velocities for our solar neighborhood, the authors support the current hypothesis that the sun is located at a considerable distance from the main body of our own stellar system.

HONORARY DEGREE FOR REV. T. E. R. PHILLIPS

On February 28th, the University of Oxford conferred on the genial Rev. T. E. R. Phillips, retired rector of Headley, astronomer, meteorologist, and botanist, the degree D.Sc., *honoris causa*. Astronomically, Mr. Phillips is best known for his studies of the surface features of Jupiter. He also made measurements of double stars and a noteworthy analysis of light curves of long-period variable stars. He has been president of the British Astronomical Society, of the Royal Astronomical Society, and of Commission 16 (concerned with planets) of the International Astronomical Union.

HISTORY OF NEW ZEALAND ASTRONOMY

The New Zealand Astronomical Society has been contemplating the compilation of a history of New Zealand astronomy. An anonymous gift of £100, £90 of which are to go toward the publication of the history, makes the realization of the hopes of the society appear possible. The gift, coming at about the time of the completion of the new Carter Observatory, in Wellington, serves to commemorate an important epoch in the history of astronomy in that country, where the science has long flourished.

The society, founded in 1920, has for its stated aims "the encouragement of interest in astronomy; the association of astronomical observers and other persons interested in astronomy for their mutual help and organization for astronomical work; the publication and circulation of astronomical information; the advancement of astronomy and of subjects related thereto." It publishes the journal, *Southern Stars*.

BOOKS AND THE SKY

THE STARS IN MYTH AND FACT

ORAL E. SCOTT. Caxton Printers, Ltd., Caldwell, Idaho, 1942. 374 pages. $3.00.

SOMETIMES a layman can write in a manner which helps the reading layman to get to the meat of the matter more directly, and consequently more effectively, than might be the case if a technical man were doing the writing. Such has not actually been the case in the realm of astronomy books, for there have been a number of works by well-established authorities which have been written in a style which the most casual tyro can grasp. However, when a layman has a new idea—a new slant—there is every justification for the creation of a new volume which may be of value.

Oral E. Scott has produced a book which is, on the surface, a combination of a general elementary descriptive astronomy, and a collection of the legends and myths which grew up around the constellations throughout the ages. He has done a good job in collecting between two covers a large amount of material which will make interesting reading for those who wish simply to skim the surface, without regard to possible misconstruction or misinterpretation.

Unfortunately from an astronomical viewpoint, the author unduly stresses the symbolism of the stars from the viewpoint of "the ancient astronomical religion," "astro-philosophy," and "psychology." Not that these should not be included—they belong in any work which purports to be an exhaustive treatise on the legends of the stars, but the sermonizing on aspects and decans which accompanies virtually every section does not harmonize too well with the presumably astronomical character of the book. The author makes it a point to indicate that modern astronomers don't believe in any of these influences, which he then proceeds to quote in very fulsome detail, almost as if astronomers are the only unbelievers.

For example, the story of Perseus is well told, as are the stories of the other constellations. If it stopped there, one would have little question. But here's the conclusion:

"There is much sound psychology in this myth, and the authors of the story and the creators of the star pictures must have had considerable understanding of the psychic laws. To look upon things through (sic) the mirror of a clean mind is to destroy their power. Denial of evil does not destroy it, but the sword of knowledge is the best of offensive weapons. The shield of aspiration protects one from the power of evil, if he will but use it. The force of the objective or reasoning mind renders one invisible, and enables him to escape from an evil environment." And plenty more of the same on pages before and after.

In his preface the author says: "No claim is based upon personal research, but care has been taken that no statement of fact or version lacks reputable authority. In such matters as distances, composition, size and other mechanical properties of the heavenly bodies, that authority is easily recognized." This book is published in 1942, but on page 56 it is stated that Jupiter has nine moons. Or aren't they mechanical properties?

I expect to see *The Stars in Myth and Fact* extensively and favorably reviewed in astrology magazines—if I see the magazines. Perhaps Mr. Scott did *not* write this book to help astrologers to be more familiar with astronomy, and thereby add scientific glibness to their patter. However, if it had been written with that purpose, he could not have done the job better.

ARMAND N. SPITZ
The Franklin Institute

THE OBSERVER'S BOOK ON ASTRO-NAVIGATION

FRANCIS CHICHESTER. Chemical Publishing Co., New York, 1941. 186 pages in two volumes. $1.25 each volume.

A MORE descriptive title would be "Airplane Navigation by Sun or Star." This is a pocket-size reference book, principally for the flier who understands the essentials of navigation and wants to be able to fix his position in the air by quick modern methods. The diagrams are profuse and unusually clear; necessary tables are included; the instruments involved are illustrated in careful detail.

Perhaps too advanced for most readers of a magazine such as *Sky and Telescope*, these two little volumes are invaluable for the thousands of young men who today want to fly for the Army and Navy. This book has almost every advantage, provided its user is well grounded in navigation. Its 186 pages are all meat and strictly to the point.

Each volume is small enough to go into one's pocket. The paper and binding do not recommend themselves to the eye or touch, but that is overlooked as soon as one reads: "Printed in Great Britain, 1941."

URANIA DAYTON FULLER
New York, N. Y.

NEW BOOKS RECEIVED

AN INTRODUCTION TO NAVIGATION, *William H. Barton, Jr.* 1942, *the author, Hayden Planetarium, New York, N. Y.* 32 pp. 50 cents.

For a brief course in navigation this photo-offset manual makes an excellent text, comprising a survey of fundamentals with a good number of simple problems. It was designed to accompany a course of 10 lectures given by the author in the Hayden Planetarium, and its chapter subjects coincide with those of the lectures: The Magnetic Compass, Piloting and the Sailings, Celestial and Terrestrial Spheres, Time and the Almanac, Latitude by Meridian Altitude, Line of Position, The Astronomical Triangle, Observations and Corrections, Note Keeping and Tables, Air Navigation.

A list of reference books, answers to problems, sample tables and charts are also included.

GLEANINGS FOR A. T. M.s

EDITED BY EARLE B. BROWN

FURTHER NOTE ON DIAGONALS

THE problem of diagonals was partially covered in this department in March, 1941, wherein it was pointed out that the true dimensions of the diagonal, or elliptical flat in the Newtonian telescope, could not be calculated by simple means.

The diameter of the cone of rays at the intersection of the plane of the diagonal and the optical axis is given by

$$d = g\,\frac{M - i}{F} + i$$

where d is the required diameter, M the diameter of the primary mirror, F the focal length, g the distance along the optical axis from the focal point to the diagonal, and i the diameter of the focal plane.

Now, as was indicated in the previous article, the true minor axis of the diagonal should be somewhat greater than d. Computation shows that this difference is quite small, never greater than .05 inch for any mirror less than 12½ inches of focal ratio greater than f/4. Table 1 gives the values (corrected) of the minor axis, based upon a focal plane one inch in diameter and a distance of the diagonal from the focal plane of one half the diameter of the mirror plus three inches. Other arrangements can easily be computed from the above equation.

The significant discrepancy arises from the fact that the diagonal should not be placed with its center on the optical axis. A moment's thought will show that, since the diagonal is to be placed in a *cone* (of rays) and not in a cylinder, it should be offset toward its lower end by a small amount. Just what this small amount should be is a straightforward geometrical problem, but not one whose solution can be expressed in a simple equation.

TABLE 1

Minor axis of elliptical flats for various mirror diameters and focal ratios

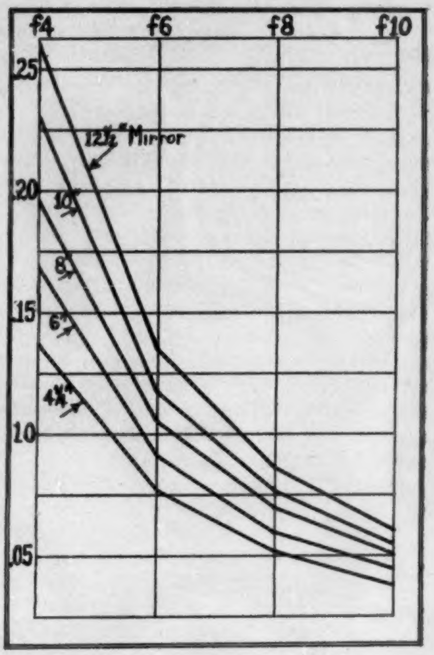
	f4	*f6*	*f8*	*f10*
4¼	2.01	1.67	1.50	1.39
6"	2.27	1.84	1.63	1.51
8"	2.56	2.03	1.79	1.62
10"	2.87	2.21	1.91	1.73
12½"	3.17	2.44	2.08	1.86

The chart indicates its values for various diameters and focal ratios. The chart is prepared on the same assumptions as is Table 1. It will be seen that the quantity is not at all insignificant. The quantities indicated in the chart are measured in the plane of the diagonal.

Of course, if the diagonal is set off-center, the out-of-focus images of the telescope will not be symmetrical. To some telescope makers this is an intolerable condition. The only remedy is to make the diagonal sufficiently large so that it may be placed centrally and still include the entire cone of rays. This will necessitate adding $\sqrt{½}$ times the offset to the minor axis.

The distance of the diagonal from the focal plane is, of course, governed by the design of the telescope itself. It will be one half the diameter of the mirror, plus the distance between edge of mirror and tube, plus the distance of the focal plane outside the tube. The diameter of the focal plane depends upon the eyepiece being used, and is equal to the diameter of the field lens of this eyepiece, nearly enough. One inch has been used in the tables, although the field-lens diameter of most eyepieces runs a little less than this.

Table 2 has been prepared to show corrections to the values given in the chart. The upper figure in each box is the change in the offset for each change of one inch in the value of g (distance from focal plane to diagonal), above or below the value of half the diameter of mirror plus three inches. The lower figure in each box is the change in the offset for each change of one inch in the value of i (diameter of focal plane) above or below the value one inch. Changes in the value of the minor axis resulting from changes in g and i can be easily computed from the equation given in the first paragraph.



Offset of diagonal in inches.

TABLE 2

Corrections to the chart for a change of one inch in g or i

		f4	*f6*	*f8*	*f10*
4¼"	g'	.013	.006	.003	.002
	i'	.047	.020	.011	.007
6"	g'	.016	.007	.004	.003
	i'	.034	.014	.008	.006
8"	g'	.018	.008	.005	.003
	i'	.027	.011	.006	.005
10"	g'	.019	.008	.005	.003
	i'	.021	.009	.005	.004
12½"	g'	.020	.009	.005	.003
	i'	.018	.008	.004	.003

CORRECTION

We regret an error in the diagram of R. S. Luce's wooden cell, published in this department last month. The mirror-clamping screw is shown threaded to the back plate, whereas it should be threaded to the cell proper. Mr. Luce is now developing an *ersatz* telescope, constructed entirely of wood (except the mirror), which will be featured here in the near future. A corrected diagram of the cell will be published at that time.

GLEANINGS is always open for comments, contributions, suggestions, and questions, from its readers. We are here to serve, in every possible way, those of the telescope-making fraternity who are among the readers of *Sky and Telescope*.

ASTRONOMICAL ANECDOTES

STARS VISIBLE BY DAY? JUST GRAZING; "WHAT SCIENCE SAYS TO TRUTH."

LAST month there was mention of some old issues of the journal, *Nature*, but I didn't say why I had been browsing among them. I remembered some vague thing concerning the visibility of stars by day, coming out of Europe at about that time, and I knew there would be some reference to it in that excellent British weekly. Sure enough, there was a brief condensation of the remarks of M. G. Bigourdan before the French Academy, and references to *Comptes Rendus*, which I then consulted, only to find them not too good, and later corrected by the author.

It seems that as early as March 1, 1611, Mercury was seen in broad daylight with a telescope; the observer was Peiresc. Not until May 2, 1632, do we find that W. Schickard first observed a star, Regulus, in daylight with a telescope. Much of the difficulty in finding a star by day, back in the 17th century, must have been due to inferior telescope mountings. In mid-January of this year, I found Vega to be very conspicuous in a 3-inch finder of 30 power, about a half hour before sunset. By diaphragming the objective, I found that I could still see it, with an aperture of a third of an inch, but not with an aperture of only one quarter inch, due to a strange mottled pattern in the field; a sort of knife-edge effect, showing (I presume) the lemon-peel finish of the finder objective, preventing seeing the much blown-up image of Vega.

On January 29th, Venus was easily seen at once, at 1 p.m., with this same 3-inch finder; it was then only 10 degrees from the sun, and was readily picked up with 8-power binoculars at 5 p.m., and with the naked eye at 5:15, that same day, just at sunset. A pair of bird glasses, magnifying only two diameters, easily showed the crescent of the planet. Bad weather prevented my following the planet on succeeding days.

But how about stars visible with the naked eye, by day? Of course, we have all heard the tale of someone who had an uncle that had a neighbor who had a well so deep that stars could be seen from the bottom of it! The Rev. W. F. A. Ellison (well known to amateur telescope makers) disposed of this idea very cleanly in the *Journal* of the British Astronomical Association (Vol. 26, p. 227, 1916), when he said,

> It is a well-known popular belief that the stars can be seen in daylight from the bottom of a deep well, shaft, or tall chimney. Like many other popular beliefs, it survives only because no one has ever taken the trouble to investigate it. . . . The whole idea is a myth. . . . Anyone who has ever actually looked up from the bottom of such a shaft (as I have from the bottom of a colliery, 900 feet below the surface) must have been struck not by the *darkness* of the little disc of sky, but by its *dazzling brilliance*.

But are stars visible to the naked eye by day? I have had small boys, totally unversed in astronomy and (what is even stranger) totally ignorant of my vocation, ask me on the street, "Mister, what is that star up there in the sky?" when they see Venus. It happened on two occasions separated by several years. Some people may remember that Venus was suddenly discovered by the Italian troops during the conquest of Ethiopia, several years ago, and the press was full of the miraculous visibility of a star by daylight! But if Venus can be so casually seen, and is only about a dozen times brighter than Sirius, why do we not have reports of Sirius visible by day? Certainly it should be seen, especially if one points a telescope to it first. As a matter of fact, there is on record at least one report of Sirius as visible "some minutes before sunset" on April 18, 1916; this is recorded in *Observatory* for June, 1916.

In February I saw Jupiter, with the unaided eye, at 3 p.m., after having set the telescope on it, and spending a great amount of time getting my eye focused on infinity. It was hard to see, because, very likely, of the very real size of that planet. I had to look, then rest, then look again, several times, before I was sure that I could honestly say I saw it.

Those who never browse through old journals miss a lot of fun. But here I must digress for a moment to recall a story told by Catherine Frost, the very charming daughter of the late director of Yerkes Observatory. She is one of the proprietors of the Concord Bookshop, on Michigan Avenue in Chicago, and she told one day of a lady who was looking through some of the books in the shop. Miss Frost went to her and asked if she could be of assistance, and the lady replied, "No, thank you; I'm just grazing"!

I found another very good thing in that pile of old copies of *Nature* for 1916. Very often scientists are misunderstood; very often scientists misunderstand, or at least forget for a moment, the relationship of their findings to ultimate truth. This is not primarily a problem for philosophers; each scientist must recognize his and his colleagues' findings as forming a part of the picture of the universe as drawn by man, and not as it may be in truth. Sir Isaac Newton was very wise in insisting that he was describing only the behavior of the thing called gravitation, and not the true nature of the thing itself. "Attraction," to him, meant only "tendency to produce motion toward."

In Volume 97 of *Nature*, page 344 (1916), a Mr. William Watson has this:

WHAT SCIENCE SAYS TO TRUTH

As is the mainland to the sea,
Thou are to me;
Thou standest stable, while against
thy feet
I beat, I beat!

Yet from thy cliffs so sheer, so tall,
Sands crumble and fall;
And golden grains of thee my tides
each day
Carry away.

Newton had said much the same thing, more or less reversing the simile, when he wrote:

> I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me.

R. K. M.

OBSERVER'S PAGE

By Jesse A. Fitzpatrick

Occultation Predictions

THERE are so many requests each month by letter and telephone for information about the list of occultations published on the "Observer's Page," I think that an explanation of the methods employed for determining the predicted time and position angle of immersion and emersion is in order.

On pages 369 to 380 of the 1942 *American Ephemeris and Nautical Almanac*, there are lists of occultations which may be observed from any of four selected stations in the United States. The predicted time for each immersion and emersion is given, as well as the position angles. The variations of this time per degree of latitude and longitude are noted in the columns headed respectively *a* and *b* and are usually called the *a* and *b* quantities. A detailed explanation of their use is given on page 620 and does not need repetition. I employ this method in determining the predicted times for the occultations listed for our local station in New York City.

A great many amateur astronomers evidently assume the use of the *a* and *b* quantities should give results accurate to within two or three seconds and are disappointed when they observe an immersion 30 or 40 seconds early or late. This method is not intended to give accuracy, but is merely a convenience for busy astronomers who wish to time an occultation and can, by using these quantities, compute in five minutes the approximate moment when an occultation will occur at their place of observation.

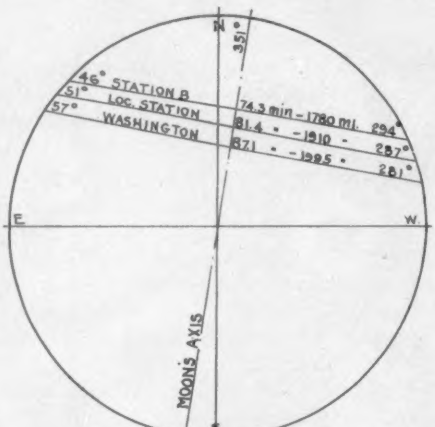
Even the long and detailed method shown on pages 617 to 620 of the *Ephemeris* is not absolutely accurate because the geocentric conjunction of the moon and star is given in decimals of a minute, which can make the final result incorrect by a few seconds.

If an observer lives within 200 miles of one of the standard stations of the *Ephemeris*, he should, as a general rule, be able to predict an immersion or emersion, by using the *a* and *b* quantities, to within 30 or 40 seconds. The local station in New York City (Columbia University Observatory), which I use as a basis for my predictions, is nearly 200 miles from the standard station at Washington, D. C., and 120 miles from the standard station, long. 72° 30′ west, lat. 42° 30′, which I shall call station *B*, and which is a few miles north of Amherst College in Massachusetts. I use both of these stations when making my predictions and find in a majority of cases that the nearer station, *B*, gives more accurate results. This is not always the case. The occultations of λ Capricorni on November 24th and of Aldebaran on December 30th were correct within three seconds and ½ second, respectively, as figured from Washington, and varied 33 and 12.5 seconds using the *B* station quantities.

In my February list the results from both stations were very nearly the same in all cases but one. The occultation of 318 B Tauri on February 23rd would have begun at 7:18.1 (Eastern Standard Time) if figured from Washington and at 7:23.6 if figured from station *B*. In the March list there is a variation of 3.4 minutes in the case of 24 Scorpii. However, these wide differences are unusual, and are only mentioned so that an observer relying on the *a* and *b* quantities will understand that he might occasionally find a large variation between the predicted and actual times.

The position angle is of extreme importance in timing emersions. A fairly accurate knowledge of the place on the edge of the moon where the star will emerge will enable the observer to concentrate on that spot. This is very necessary because of the difficulty in seeing the star at the exact instant of emersion when it occurs at the bright limb; while at the dark limb, after full moon, many seconds can be lost in locating the star if the telescope is not aimed at the right place.

The approximate position angles of both immersion and emersion can be determined in a very simple way. Draw a circle representing the circumference of the moon on any convenient scale and mark every five degrees on the edge. We shall use for an example the occultation of Aldebaran on March 22nd. On page 369 of the *Ephemeris* we note the immersion at Washington at 57° and emersion at 281°, with time of transit, 87.1 minutes. Draw a line on the circle connecting these points and mark it 87.1. On page 372 we note the immersion at station *B* at 46° and emersion at 294°, transit time,



74.3 minutes. Connect these points and label the line 74.3. The two lines are nearly parallel. By using the *a* and *b* quantities we find the time of transit at our local station to be 81.4 minutes. At some position between the lines already drawn, we draw a line 81.4 units long and as nearly parallel as possible to the other two. Where this line intersects the circumference of the circle are the approximate points where immersion and emersion will occur. This is not mathematically exact, but close enough for the observer's needs.

A slightly more accurate method of locating these points is by drawing the circle to an accurate scale representing the diameter of the moon, 2,160 miles. In this case, the distance the star would apparently travel behind the moon as seen from Washington would scale 1,995 miles and from station *B*, 1,780 miles. Dividing these distances by the times of transit, we find the respective average speeds to be 22.9 and 23.9 miles per minute. Selecting a speed halfway between these, and multiplying by the transit time at the local station, we obtain a chord distance of 1,910 miles. This chord intersects the circumference at 51° and 287°.

Since the position angles are measured eastward around the circumference of the moon from its north point, it is essential to know exactly where this point lies. The position angle of the moon's axis of rotation for every day in the year is given in the *Ephemeris* on pages 402 to 409. We have found the immersion of Aldebaran to be at 51° from the north point and emersion at 287°. The position angle of the moon's axis for the time of the occultation is about 351°, or 9° west of north. Therefore, the immersion of Aldebaran will occur 60° from the moon's north pole, and the emersion 296° from the pole. A good rule to remember is that if the position angle of the moon's axis is between 0° and 25°, *subtract*, and if between 335° and 360°, *add* the number of degrees the north pole is east or west of the north point.

There have been many inquiries on the point just mentioned. The moon's axis of rotation is constantly appearing to swing from east to west and back again around the apparent center of the moon as a pivot. This is because the moon moves generally along or near the ecliptic, and its axis is roughly perpendicular to that circle in the sky. However, the ecliptic itself makes an angle of up to 23½° with the celestial equator, and this accounts for the greater part of the 25° which is the maximum position angle the moon's axis may assume from the north point in either direction. Whenever the moon passes over or near Aldebaran, the position angle is the 351° mentioned above, so that an observer who frequently watches occultations and conjunctions soon gets to know the position angle of the moon's axis corresponding to each important object along the moon's path.

A good chart of the moon will show 60° to be slightly north of the crater Briggs, and 296° to be about 2° north of the northern edge of the Sea of Crises. In this manner, the place to watch for Aldebaran's emergence from the occultation used in our example is determined.

PHASES OF THE MOON

Last quarter	May 7,	8:13 a.m.
New moon	May 15,	1:45 a.m.
First quarter	May 23,	5:11 a.m.
Full moon	May 30,	1:29 a.m.

The moon, at perigee on May 30th, will be closest to the earth for 1942, distance, 221,940 miles.

OCCULTATIONS—MAY, 1942

Local station—lat. 40° 48'.6, long. 4h 55.8m west.

Date		Mag.	Name	Immersion	P.*	Emersion	P.*
May	2	5.5	49 Librae	2:18.4 a.m.	135°	3:27.3 a.m.	258°
	3	6.5	90 B Ophiuchi	0:21.1 a.m.	68°	1:20.0 a.m.	318°
	5	5.4	190 B Sagittarii	2:06.2 a.m.	129°	3:04.3 a.m.	233°
	19	5.6	162 B Geminorum	10:35.2 p.m.	170°	11:00.4 p.m.	210°
	26	6.1	72 Virginis	11:45.4 p.m.	80°	0:48.2 a.m. (27)	327°

*P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

THE PLANETS IN MAY

Mercury. On May 18th there will be a favorable elongation (22° 11' east), Mercury setting one hour and 40 minutes after the sun.

Venus, in Pisces, is about magnitude —3.7. The close conjunction with the moon on the 11th will not be visible in the United States.

Mars, in Gemini, will travel through an interesting part of the Milky Way.

Jupiter will be in Taurus through the month.

Saturn and *Uranus* will be in conjunction with the sun on the 23rd and 21st, respectively.

Neptune. See diagram in the February issue.

Following the emersion of 72 Virginis on May 27th, the star l Virginis, magnitude 4.8, will be in conjunction with the moon at 1:20.3 a.m. at our local station. These two stars form an interesting pair for the amateur observer. Variously listed as 72 and l, 72 and 74, and l^1 and l^2, they are spaced 23 minutes of arc, east and west, and 13 minutes, north and south. Thus both may be occulted at the same time, which will occur on this date in the south and southwestern United States.

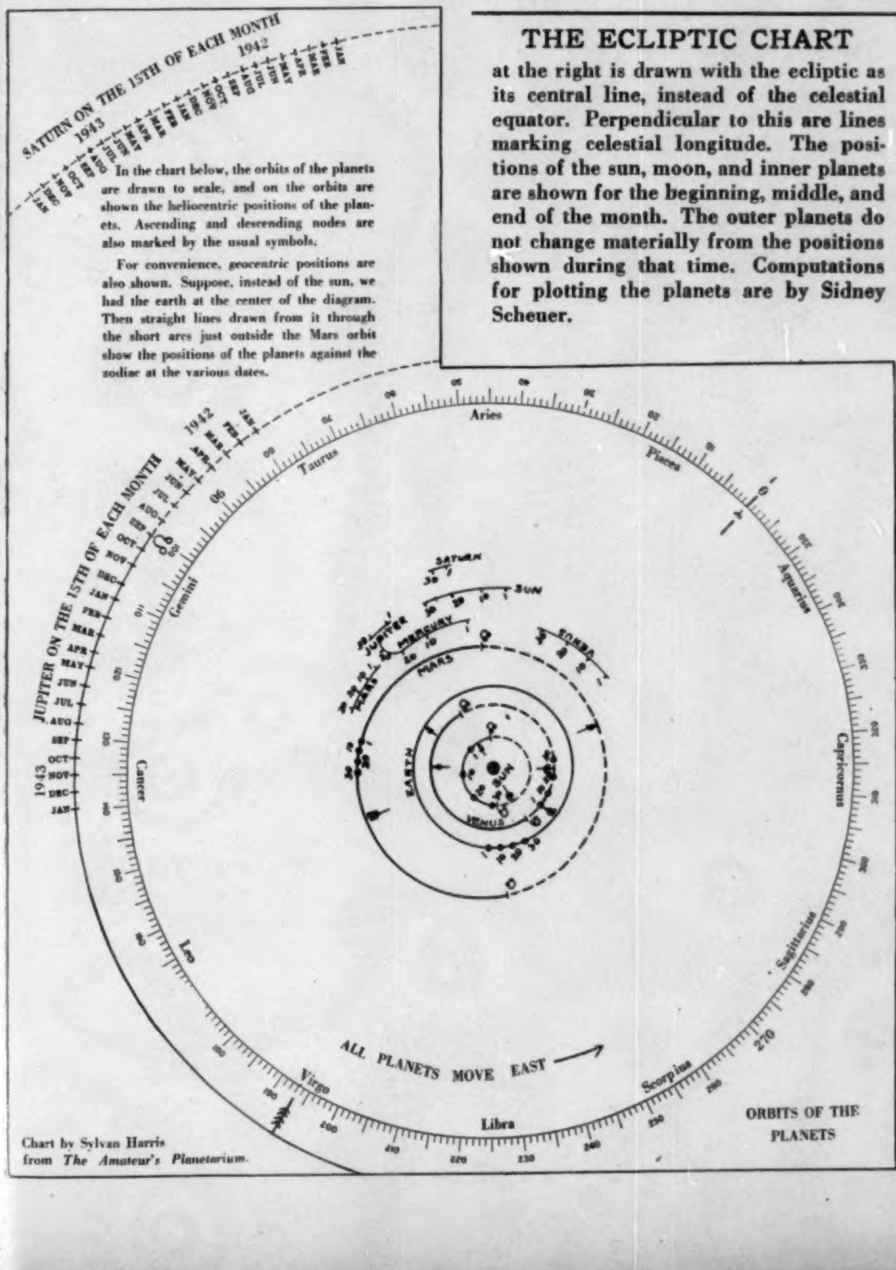
The color contrast of this pair is interesting, 72 is hot, white; 74, cool, red.

MIRA MAXIMUM

The variable star o Ceti, Mira, will be at maximum about May 15th. The northerly declination of the sun, and its corresponding early rising, will make observations of Mira difficult at this time.

THE ECLIPTIC CHART

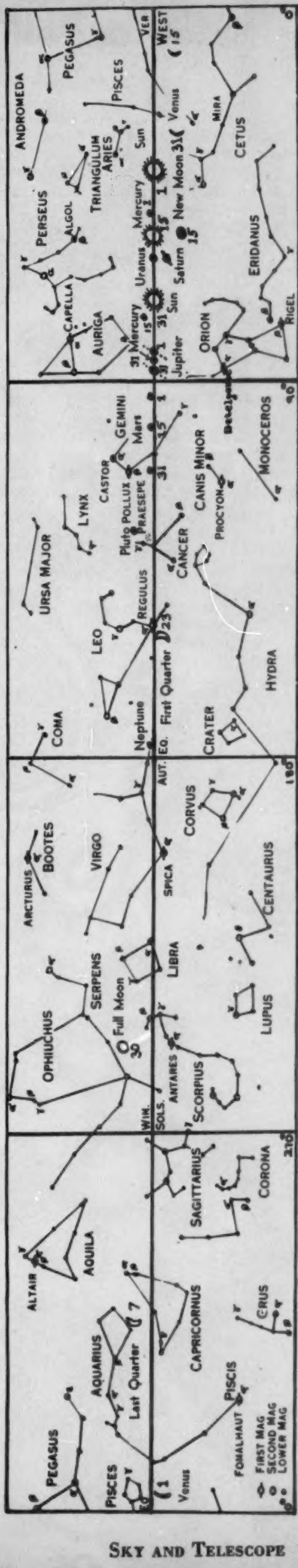
at the right is drawn with the ecliptic as its central line, instead of the celestial equator. Perpendicular to this are lines marking celestial longitude. The positions of the sun, moon, and inner planets are shown for the beginning, middle, and end of the month. The outer planets do not change materially from the positions shown during that time. Computations for plotting the planets are by Sidney Scheuer.



In the chart below, the orbits of the planets are drawn to scale, and on the orbits are shown the heliocentric positions of the planets. Ascending and descending nodes are also marked by the usual symbols.

For convenience, *geocentric* positions are also shown. Suppose, instead of the sun, we had the earth at the center of the diagram. Then straight lines drawn from it through the short arcs just outside the Mars orbit show the positions of the planets against the zodiac at the various dates.

Chart by Sylvan Harris from *The Amateur's Planetarium.*



THE APPARENT POSITIONS IN THE HEAVENS OF THE SUN, MOON, AND PLANETS.

THE STARRY HEAVENS IN MAY

BY LELAND S. COPELAND

CORVUS, the Crow, shines brightly close to the meridian in mid-May at 10 p.m. War Time. It is the outrider and northern representative of the Southern Cross. Whenever we see the Crow, we know that 40 degrees due south of it is the hidden Cross, moving in line with it as the heavens roll westward.

Both constellations have four-sided figures. Corvus is less luminous, but slightly larger, than the famous showpiece.

When the Pyramids were being built, the Southern Cross could have been seen from almost all of what is now the United States. Slowly, as a result of change in direction of the earth's axis, this bright group moved southward until at present it can be observed only from the lowest parts of Florida and Texas. At the time of Christ's crucifixion it could have been glimpsed from Jerusalem near midnight, though too low in the sky to have been impressive.

Between Crux and Corvus is a starry bent arrow, which can be seen by dwellers in the southern states. Brighter than the constellation Sagitta, it is about six degrees due north of the Cross, in Centaurus.

On the meridian at about the same time as Corvus are the Big Dipper, the Coma Berenices cluster, and the Y of Virgo.

Another noteworthy feature of May is Hydra, the largest of the constellations, nearly parallel to the horizon at 10 p.m. It stretches in a long-drawn line across the southern sky from Scorpius in the southeast to Canis Minor in the west, but only the western part is easy to find.

Shining in the northeast are Lyra and Hercules, and between Hercules and the meridian, Corona Borealis and Bootes wait for friendly eyes. In the northwest Auriga and Gemini are nearing the horizon. Gracefully the Twins descend. And west of the meridian stanchly stands the Lion, astride the ecliptic.

THE LION-GUARDED GATE

WHILE Galileo was peering through the first celestial telescopes, Shakespeare was recording his conclusion that towers and temples and all things human ultimately would vanish "like the baseless fabric" of a vision and that men themselves were made of dream-stuff. Today we know that the poet spoke more sagely than anyone could have known in 1611, because modern telescopes are telling us about more enduring realities in the far depths of heaven.

The Milky Way system rotates but once in 200 million years. This means that our own universe has made only one revolution since Paleozoic times. Within that vast interval dinosaurs, mammals, and men, each in turn, won dominance. The psalmist who said that to the Eternal a thousand years were as one day probably would have increased the estimate vastly if he had known about galaxies. But no one knew anything about them before 1612, when Simon Marius was first to observe the great spiral in Andromeda.

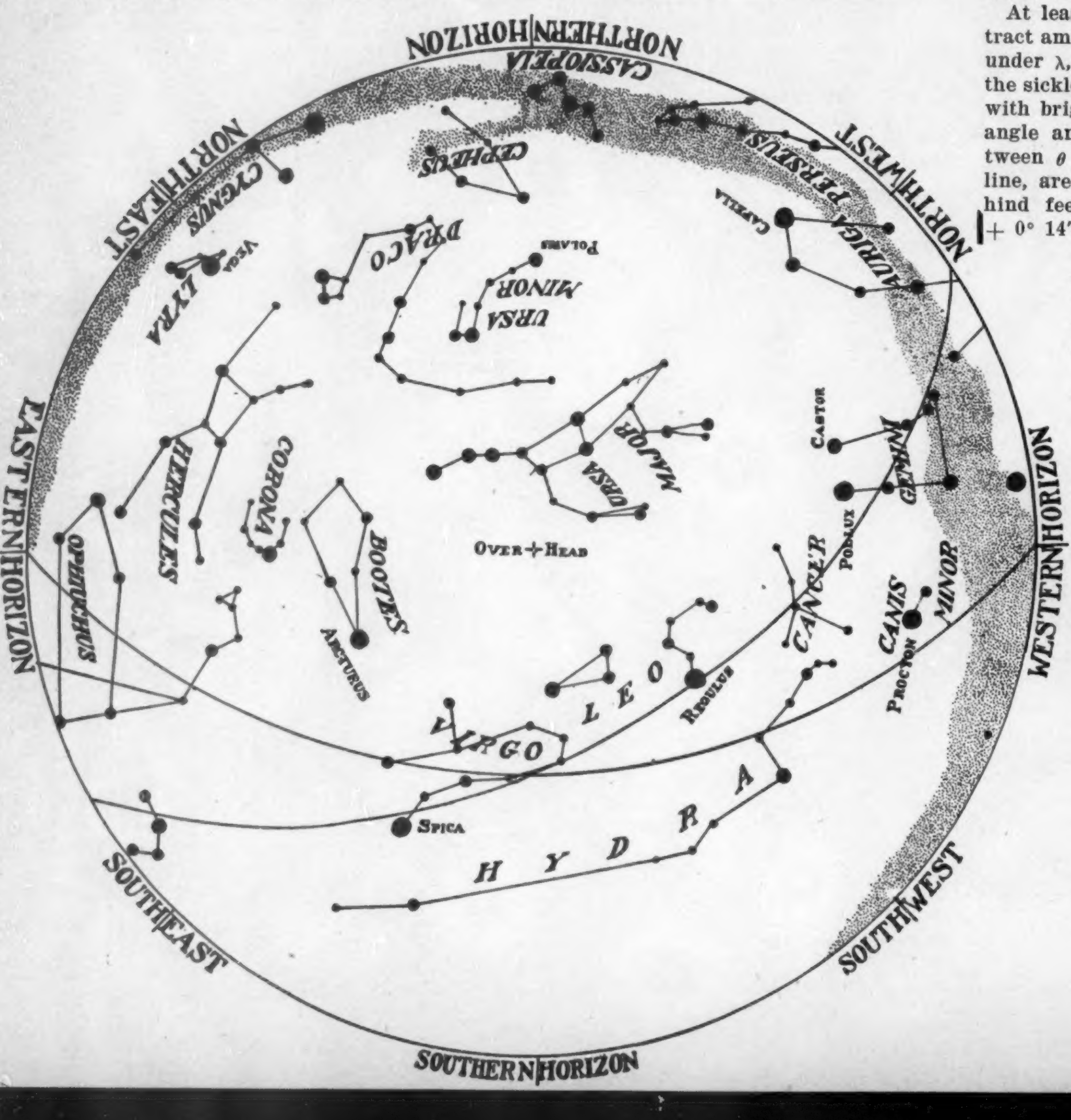
If, stirred by such thoughts, we glance skyward in May, we find that Leo, guardian of the galactic gate, is high in the western sky. As stone lions often flank the stairways to palaces and museums, so Leo watches over the grand entrance to the land of the galaxies. Behind him appear Coma Berenices, Virgo, and Canes Venatici, which, with Ursa Major, form the main galactic hunting grounds of the amateur.

To the Greeks this constellation represented the Lion of Nemea, a scourge of southern Greece. Hercules, beginning his 12 labors, first attacked this shaggy-maned menace. When he could not destroy the lion with arrows and club, he seized and killed it with his great hands. This story reminds us of Samson and his barehanded victory over the Philistine lion. Such tales, as Aesop emphasizes, were written by men, not by lions.

Leo consists largely of a sickle, his head, and a triangle, the hindquarters. Below the triangle, which includes bright Denebola, is an irregular line of stars forming a rear leg. The sickle contains two notable stars, γ or Algeiba, a handsome double, and Regulus, at the end of the handle. Within the sickle is the radiant of the November Leonids, which startled the world in 1833 and delighted it in 1866.

At least six galaxies in Leo should attract amateur telescopes this month. Just under λ, the first star beyond the tip of the sickle, is NGC 2903, an advanced spiral with bright center. Between θ of the triangle and ρ are M95 and M96, and between θ and ι, first star of the hind-leg line, are M65 and M66. Preceding Leo's hind feet appears NGC 3521 (11h 3m, $+0° 14'$).

Amateurs who look at galaxies and consider their significance will find deeper meaning in the words that Shakespeare wrote in the sunset of his thought.



THE STARS FOR MAY

as seen from mid-northern latitudes at 10 p.m., May 7th; 9 p.m., May 23rd. Magnitudes of the stars are indicated by the sizes of the disks marking the stars, and the names of some of the brighter stars appear. The ecliptic and the equator are shown, the latter touching the horizon at the east and west points. See chart on the "Observer's Page" for the positions of the sun, moon, and planets this month.

HERE AND THERE WITH AMATEURS

This is not intended as a complete list of societies, but rather to serve as a guide for persons near these centers, and to provide information for traveling amateurs who may wish to visit other groups.

City	*Organization*	*Date*	*Hour*	*Season*	*Meeting Place*	*Communicate with*
BOSTON	Bond Ast. Club	1st Thu.	8:15 p.m.	Oct.-June	Harvard Observatory	Homer D. Ricker, Harvard Observatory
"	A.T.M.s of Boston	2nd Thu.	8:15 p.m.	Sept.-June	Harvard Observatory	F. I. Noyes, 340 Warren St., Brockton, Mass.
BROOKLYN, N. Y.	Astr. Dept., B'klyn Inst.	Round Table 3rd Thu.	8:00 p.m.	Oct.-April	Brooklyn Institute	William Henry, 154 Nassau St., N. Y. C., *BA.* 7-9473
BUFFALO	A.T.M.s & Observers	1st & 3rd Fri.	8:00 p.m.	Oct.-June	Museum of Science	J. J. Davis, Museum of Science
CHATTANOOGA	Barnard A. S.	4th Fri.	7:30 p.m.	All year	Chattanooga Obs.	C. T. Jones, 1220 James Bldg., *CHat.* 6-8341
CHICAGO	Burnham A. S.	2nd & 4th Tue.	8:00 p.m.	Sept.-June	Congress Hotel	Wm. Callum, 1435 Winona Ave.
CLEVELAND	Cleveland A. S.	Fri.	8:00 p.m.	Sept.-June	Warner & Swasey Obs.	Mrs. Royce Parkin, The Cleveland Club
DAYTONA BEACH, FLA.	D. B. Stargazers	Alt. Mon.	8:00 p.m.	Nov.-June	500 S. Ridgewood Ave.	Rolland E. Stevens, 500 S. Ridgewood
DETROIT	Detroit A. S	2nd Sun.	3:00 p.m.	Sept.-June	Wayne U., Rm. 187	E. R. Phelps, Wayne University
"	Northwest A. A. S.	1st & 3rd Tue.	8:00 p.m.	Sept.-June	Redford High Sch.	A. J. Walrath, 14024 Archdale Ave.
DULUTH, MINN.	Duluth Ast. Club	1st & 3rd Sat.	8:00 p.m.	All year	Darling Observatory	W. S. Telford, 126 N. 33rd Ave. E.
FT. WORTH	Tex. Observers	No reg. meetings	....			Oscar E. Monnig, 1010 Morningside Dr.
GADSDEN, ALA.	Ala. A. A.	1st Thu.	7:30 p.m.	All year	Ala. Power Auditorium	Brent L. Harrell, 1176 *W* or 55
INDIANAPOLIS	Indiana A. A.	1st Sun.	2:00 p.m.	All year	Central Library Audit.	E. W. Johnson, 808 Peoples Bank Bldg.
JOLIET, ILL.	Joliet A. S.	Alt. Tue.	8:00 p.m.	Oct.-May	Jol. Mus. & Art Gallery	Monica L. Price, 403 Second Ave.
LOS ANGELES	L. A. A. S.	2nd Thu.	8:15 p.m.	......	2606 W. 8th St.	Charles Ross, 2606 W. 8th St.
LOUISVILLE, KY.	L'ville A. S.	3rd Tue.	8:00 p.m.	Sept.-May	Women's Bldg., Univ. of Louisville	Mary Eberhard, 3-102 Crescent Ct., *Taylor* 4157
MADISON, WIS.	Mad. A. S.	2nd Wed.	8:00 p.m.	All year	Washburn Observatory	C. M. Huffer, Univ. of Wisconsin
MILWAUKEE	Milw. A. S.	1st Thu.	8:00 p.m.	Oct.-May	Marquette U., Eng. Col.	E. A. Halbach, *Hopkins* 4748
MOLINE, ILL.	Pop. Ast. Club	2nd Tue.	7:30 p.m.	All year	Sky Ridge Observatory	Carl H. Gamble, Route 1
NEW HAVEN	New Haven A. A. S.	1st Sat.	8:00 p.m.	Sept.-June	Yale Observatory	F. R. Burnham, 820 Townsend Ave., 4-2618
NEW YORK	A. A. A.	1st & 3rd Wed.	8:15 p.m.	Oct.-May	Amer. Mus. Nat. Hist.	G. V. Plachy, Hayden Plan., *EN.* 2-8500
" "	Junior Ast. Club	Alt. Sat.	8:00 p.m.	Oct.-May	Amer. Mus. Nat. Hist.	J. B. Rothschild, Hayden Plan., *EN.* 2-8500
NORWALK, CONN.	Norwalk Ast. Soc.	Last Fri.	8:00 p.m.	Sept.-June	Private houses	Mrs. A. Hamilton, 4 Union Pk., 6-4297
OAKLAND, CAL.	Eastbay A. A.	1st Sat.	8:00 p.m.	Sept.-June	Chabot Observatory	Miss H. E. Neall, 6557 Whitney St.
PHILADELPHIA	A.A. of F.I.	3rd Fri.	8:00 p.m.	All year	The Franklin Institute	Edwin F. Bailey, *Rit.* 3050
"	Rittenhouse A. S.	2nd Fri.	8:00 p.m.	Oct.-May	The Franklin Institute	A. C. Schock, *Rit.* 3050
PITTSBURGH	A. A. A. of P'burgh	2nd Fri.	8:00 p.m.	Sept.-June	Buhl Planetarium	F. M. Garland, 1006 Davis Ave., N.S.
PONTIAC, MICH.	Pontiac A. A. A.	2nd Mon.	8:00 p.m.	All year	Cranbrook Inst. of Sci.	J. P. Coder, 2675 Voorheis Rd., 2-9419
PORTLAND, ME.	A. S. of Maine	2nd Fri.	8:00 p.m.	All year	Private Homes	H. M. Harris, 27 Victory Ave., S. Portland
PROVIDENCE, R. I.	Skyscrapers	1st Wed.	8:00 p.m.	All year	Wilson Hall, Brown U.	Ladd Obs., Brown U., *GA.* 1633
READING, PA.	Reading-Berks A. C.	2nd Thu.	8:00 p.m.	Sept.-June	Albright College	Mrs. F. P. Babb, 2708 Filbert Ave.
RENO, NEV.	A. S. of Nev.	4th Wed.	....	All year	Univ. of Nevada	G. B. Blair, University of Nevada
ROCHESTER, N. Y.	Roch. Ast. Club	Alt. Fri.	8:00 p.m.	Oct.-May	Eastman Bldg., Univ. of Rochester	P. W. Stevens, 1179 Lake Ave., *Glenwood* 5233-*R*
SAN ANTONIO	San Ant. A. A.	3rd Mon.	8:00 p.m.	All year	Le Villela	R. B. Poage, 807 Hammond Ave.
SCHENECTADY	S'tady Ast. Club	3rd Mon.	8:00 p.m.	All year	Observatory site	C. H. Chapman, 216 Glen Ave., Scotia
SOUTH BEND, IND.	St. Joseph Val. Ast.	Last Tue.	8:00 p.m.	All year	928 Oak St.	Fannie Mae Chupp, 224 Seebirt Pl.
STAMFORD, CONN.	Stamford Ast. Soc.	4th Wed.	8:00 p.m.	All year	Stamford Museum	Thomas Page, Stamford Mus., 300 Main St.
TACOMA, WASH.	Tacoma A. A.	1st Mon.	....	All year	Coll. of Puget Sound	Geo. Croston, *Gar.* 4124
WASHINGTON, D. C.	Nat'l. Cap. A. A. A.	1st Sat.	8:00 p.m.	Oct.-June	U. S. Nat'l. Museum	Stephen Nagy, 104 C St., N.E., *Linc.* 9487-J
WICHITA, KANS.	Wichita A. S.	2nd Tue.	8:00 p.m.	All year	East High Sch., Rm. 214	S. S. Whitehead, 2322 E. Douglas, 33148

Sky and Telescope is official publication of many of these societies.

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PLANETARIUM NOTES

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ THE BUHL PLANETARIUM presents, to *May 15th,* COLORS IN THE SKY.

Familiar as we are with the variety of colors with which nature paints the earth, most of us are not aware of the amazing wealth of color to be found in the heavens. In this sky show, Buhl Planetarium visitors see not only such things as sunsets and eclipses and the tinted northern lights, but the many startling colors concealed in stars and planets and nebulae. We find that the green and orange mottling the globe of Mars becomes pale and drab compared to the beautiful rainbows hidden in the stars themselves.

From *May 16th,* MODERN SKY PICTURES—By Cy Hungerford.

The famous cartoonist, Cy Hungerford, turns his talent for humorous and trenchant characterization to the heavens, revamping the star pictures traced by the ancients and presenting them in modern dress. Have you found it difficult to see in the stars of Cetus the figure of a sea-monster? Or a winged horse in the stars of Pegasus? Has it been easier for you to imagine other objects more familiar to us in the streamlined world of 1942? In this sky show is your chance to see the quaint sky characters of antiquity modernized before your eyes.

★ THE HAYDEN PLANETARIUM presents, *to May 31st,* WEATHER SIGNS IN THE SKY. (See page 7.)

From time immemorial the sky has been scanned for weather signs. Clouds, moon, sun, rainbows, halos, and even the stars have played their part (and do yet, for that matter) in forecasting the weather. Today, with the modern science of meteorology, much of this has become lore. But despite the many superstitions that are untrue, you can read weather signs in the sky.

From *June 1st to 30th,* THE PLANETS.

New things are constantly being learned about our neighbors, the planets. Plainly seen as morning and evening stars, they are always a topic of interest. Why do the planets appear to move so strangely? In what ways are they like our world, and how do they differ? Just what do we know about them and how did we find it out?

★ SCHEDULE BUHL PLANETARIUM

Mondays through Fridays .... 3, 8, and 9 p.m.
Saturdays .... 2, 3, 8, and 9 p.m.
Sundays and Holidays .... 3, 4, 8, and 9 p.m.

★ STAFF—*Director,* Arthur L. Draper; *Lecturer,* Nicholas E. Wagman; *Business Manager,* Frank S. McGary; *Public Relations,* John J. Grove; *Curator of Exhibits,* Fitz-Hugh Marshall, Jr.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays .... 2, 3:30, and 8:30 p.m.
Saturdays .... 11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays—Mutual Network Broadcast—Coast-to-Coast.... 9:30-10:00 a.m.
Sundays and Holidays .... 2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator,* Clyde Fisher; *Curator,* William H. Barton, Jr.; *Assistant Curators,* Marian Lockwood, Robert R. Coles; *Staff Assistant,* Fred Raiser; *Lecturers,* Alden E. Moore, Asa Tenney, John Ball, Jr.